Part 2

Detailed Performance Data

Introduction to NASA's Detailed Performance Data

The four-part Mission Statement and ten Strategic Goals in NASA's Strategic Plan provide the framework for the Agency's annual performance plan that is part of NASA's Integrated Budget and Performance Document. As in previous years, NASA's FY 2004 performance plan included long-term Performance Objectives and Annual Performance Goals (APGs). But, in FY 2004, NASA addressed the difficult task of measuring annual performance against long-term research and development goals by adding a new set of mid-range measures called Performance Outcomes to help the Agency track and evaluate progress at a more meaningful level. These Outcomes enable NASA to focus and report on multi-year efforts more accurately and to provide a clearer picture of planned and actual performance on an annual and multi-year basis.

NASA's Mission	NASA's Strategic Goals
To Understand and Protect our Home Planet	Goal 1: Understand the Earth system and apply Earth system science to improve prediction of climate, weather, and natural hazards.
	Goal 2: Enable a safer, more secure, efficient, and environmentally friendly air transportation system.
	Goal 3: Create a more secure world and improve the quality of life by investing in technologies and collaborating with other agencies, industry, and academia.
To Explore the Universe and Search for Life	Goal 4: Explore the fundamental principles of physics, chemistry, and biology through research in the unique natural laboratory of space.
	Goal 5: Explore the solar system and the universe beyond, understand the origin and evolution of life, and search for evidence of life elsewhere.
To Inspire the Next Generation of Explorers	Goal 6: Inspire and motivate students to pursue careers in science, technology, engineering, and mathematics.
	Goal 7: Engage the public in shaping and sharing the experience of exploration and discovery
As Only NASA Can: Exploration Capabilities	Goal 8: Ensure the provision of space access, and improve it by increasing safety, reliability, and affordability.
	Goal 9: Extend the duration and boundaries of human space flight to create new opportunities for exploration and discovery.
	Goal 10: Enable revolutionary capabilities through new technology.

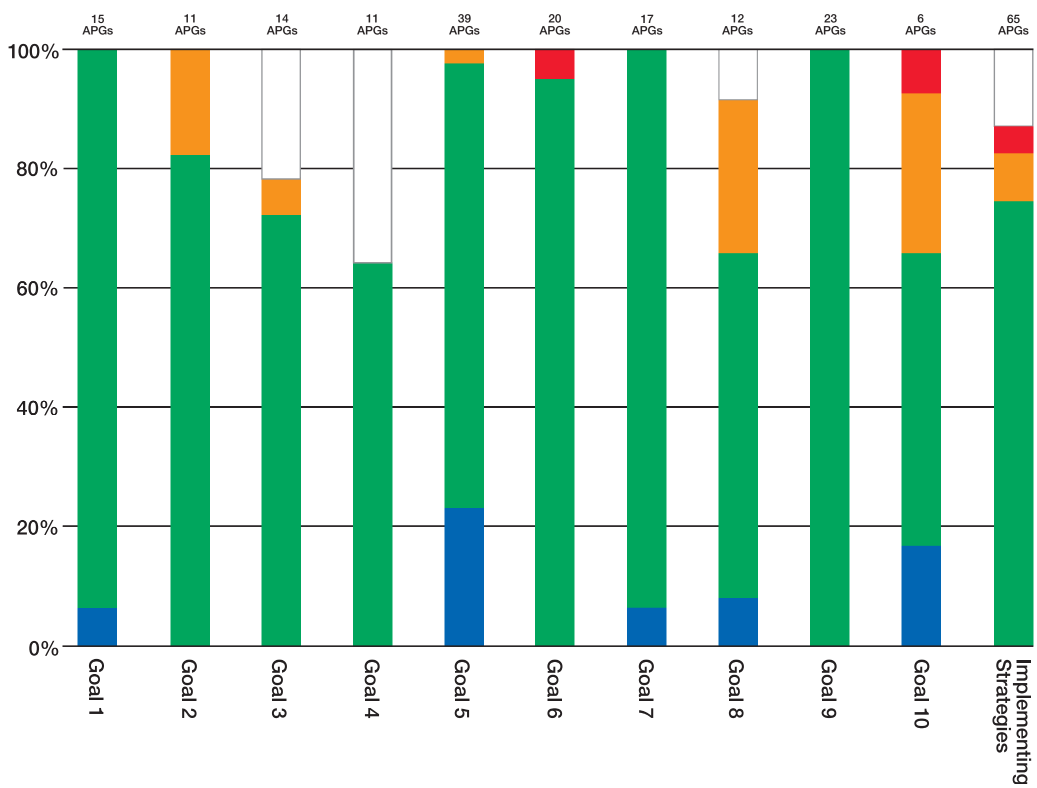
Part 1 of this report, "Management Discussion and Analysis," presented NASA's performance achievement highlights by Mission and Strategic Goal. Part 2 of this report, "Detailed Performance Data," describes each of the Performance Objectives within these Goals and provides a detailed performance report and color rating for each Performance Outcome. Part 2 also includes color ratings for each APG, as well as APG trend data for up to four years, where applicable. (Performance ratings for NASA's Implementing Strategies, including three types of Uniform Measures, are located at the end of Part 2, preceded by a brief explanation of their purpose and organization.) Finally, Part 2 includes NASA's Performance Improvement Plan addressing all Performance Outcomes and APGs that were not fully achieved in FY 2004.

The APG and Performance Outcome ratings in Part 2 reflect NASA management's intense efforts to evaluate thoroughly and objectively the Agency's performance based on all data available as of September 30, 2004. Internal reviewers (NASA employees and managers at many levels across the Agency) reviewed the performance results and recommended APG color ratings to NASA senior officials. In addition, in many cases, external reviewers (e.g., highly qualified individuals, advisory boards, and advisory councils outside NASA) assisted in this evaluation process by reviewing the same performance results and independently recommending specific APG color ratings. Following careful assessment of all performance data and results, as well as the color rating recommendations of both the internal and external reviewers, NASA senior management officials assigned color ratings to each APG using the following color rating criteria:

- Blue: Significantly exceeded APG
- Green: Achieved APG
- Yellow: Failed to achieve APG, progress was significant, and achievement is anticipated within the next fiscal year.
- Red: Failed to achieve APG, do not anticipate completion within the next fiscal year.
- White: APG was postponed or cancelled by management directive.

Next, NASA management, again aided in many cases by recommendations from internal and external reviewers, assigned color ratings to each Performance Outcome. (Note: Performance Outcome ratings are not averages of APG ratings, and they are not based solely on the Agency's performance in the current fiscal year. Performance Outcome ratings are based on NASA's progress toward achieving its multi-year goal. Therefore, it is possible to have APGs rated Yellow or Red, and still be on target to achieve a Performance Outcome as stated.) NASA senior management officials assigned color ratings to each Performance Outcome using the following color rating criteria:

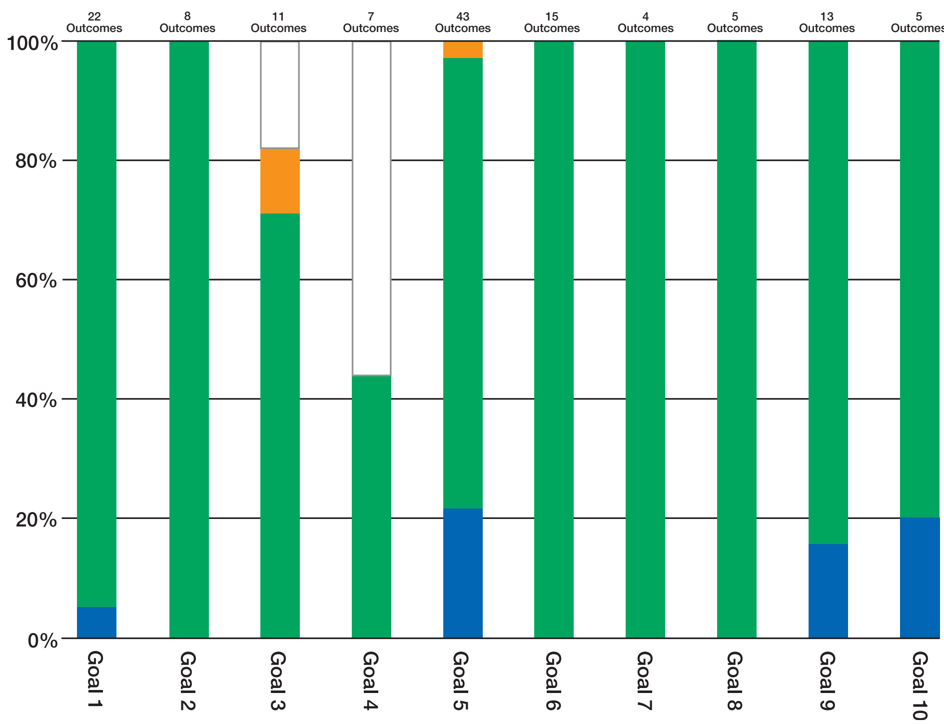
Figure 59 provides a summary of NASA's FY 2004 APG performance by Strategic Goal.



- Blue: Significantly exceeded all APGs. On track to exceed this Outcome as stated.
- Green: Achieved most APGs. On track to fully achieve this Outcome as stated.
- Yellow: Progress toward this outcome was significant. However, this Outcome may not be achieved as stated.
- Red: Failed to achieve most APGs. Do not expect to achieve this Outcome as stated.
- White: This Outcome as stated was postponed or cancelled by management directive or the outcome is no longer applicable as stated based on management changes to the APGs.

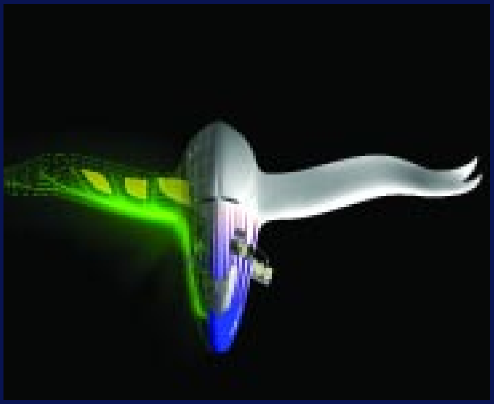
NASA is including a Performance Improvement Plan in this year's report. This Plan addresses, in detail, each APG and Performance Outcome that was not fully achieved (rated Blue or Green) in FY 2004. For each unmet Performance Outcome or APG, this Plan presents an explanation as to why the metric was not met and how NASA plans to improve performance in this metric (or why NASA will be eliminating this metric) in the future. This Plan also demonstrates how future performance improvements will enable NASA to fully achieve many Performance Outcomes in spite of current year APG ratings of Yellow or Red.

Figure 60 provides a summary of NASA's FY 2004 Outcome performance by Strategic Goal.



Mission: To Understand and Protect Our Home Planet

Goal 1: Understand the Earth system and apply Earth system science to improve prediction of climate, weather, and natural hazards.



Goal 2: Enable a safer, more secure, efficient, and environmentally friendly air transportation system.

Goal 3: Create a more secure world and improve the quality of life by investing in technologies and collaborating with other agencies, industry, and academia.

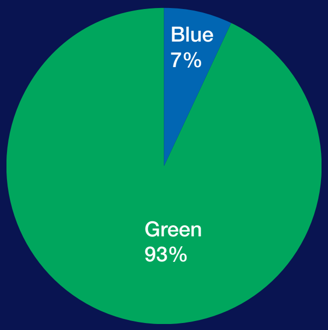
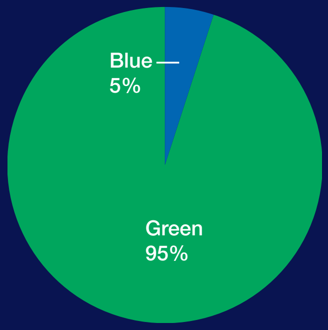


Figure 61: NASA achieved 100 percent of the APGs in Goal 1.



NASA is on track to achieve 100 percent of its Outcomes under Goal 1.

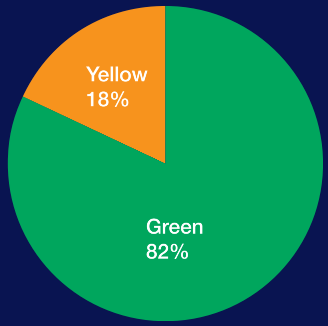
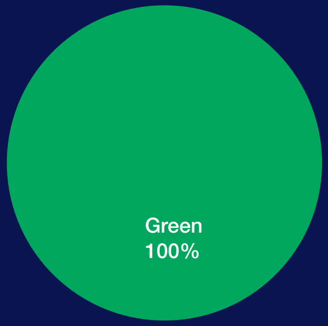


Figure 62: NASA achieved 82 percent of the APGs in Goal 2.



NASA is on track to achieve 100 percent of its Outcomes under Goal 2.

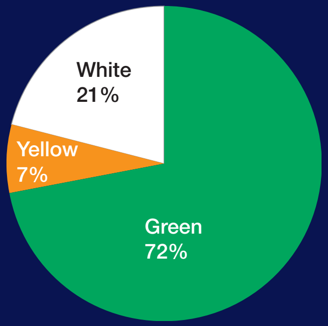
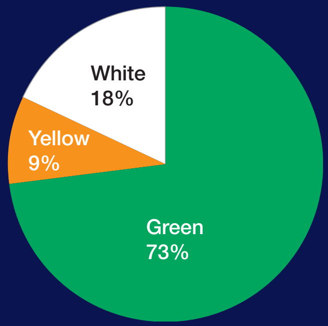


Figure 63: NASA achieved 72 percent of the APGs in Goal 3.



NASA is on track to achieve 73 percent of its Outcomes under Goal 3.

APG color ratings:

- Blue: Significantly exceeded APG
- Green: Achieved APG
- Yellow: Failed to achieve APG, progress was significant, and achievement is anticipated within the next fiscal year.
- Red: Failed to achieve APG, do not anticipate completion within the next fiscal year.
- White: APG was postponed or cancelled by management directive.

Outcome color ratings:

- Blue: Significantly exceeded all APGs. On track to exceed this Outcome as stated.
- Green: Achieved most APGs. On track to fully achieve this Outcome as stated.
- Yellow: Progress toward this Outcome was significant. However, this Outcome may not be achieved as stated.
- Red: Failed to achieve most APGs. Do not expect to achieve this Outcome as stated.
- White: This outcome as stated was postponed or cancelled by management directive or the Outcome is no longer applicable as stated based on management changes to the APGs.

Goal 1 Understand the Earth system and apply Earth system science to improve prediction of climate, weather, and natural hazards.

OBJECTIVE 1.1

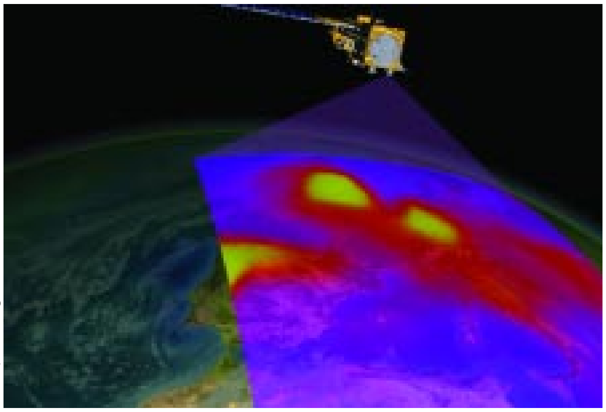
Understand how the Earth is changing, better predict change, and understand the consequences for life on Earth.

NASA Science—Ozone Recovery

A number of human-made chemicals, such as chlorine, chlorofluorocarbons, and halons, create a complex chemical reaction in the atmosphere that ultimately destroys ozone, a form of oxygen that protects Earth from the Sun's biologically harmful ultraviolet radiation. In 1987, the international community ratified the Montreal Protocol on Substances that Deplete the Ozone Layer to restrict the manufacture of these chemicals. NASA Earth science missions measure the amounts of ozone and ozone-depleting chemicals in the atmosphere to determine if this critical protective layer is recovering as ozone-depleting chemicals are phased out.

WHY PURSUE OBJECTIVE 1.1?

Earth is a dynamic place of constant change. Each change—from dramatic, fast-moving storms to slow average temperature shifts—affects our lives. The atmosphere, continents, oceans, ice, and life interact to form the complex Earth system. NASA's view from space affords researchers a unique perspective on how global change affects specific regions and how local changes have global consequences. NASA and the Agency's partners in the science community are addressing key science questions about the ever-changing Earth system. NASA pursues the answers to these questions using a systems approach that includes observation from the Agency's comprehensive suite of Earth observing satellites, research and data analysis, modeling, and scientific assessment. The results of these efforts enhance the ability of researchers to predict Earth system events and to understand what consequences these events hold for life on Earth.



Credit: NASA/Goddard Space Flight Center Sciientific Visualization Studio

Figure 64: On June 19, 2004, NASA launched Aura, a next-generation Earth-observing satellite. One of several instruments on the Aura satellite is the Ozone Monitoring Instrument, a contribution of the Netherland's Agency for Aerospace Programs and the Finnish Meteorological Institute. This instrument monitors total ozone and other atmospheric parameters related to ozone chemistry and climate. In this simulation, Aura passes over Europe collecting data.

NASA'S PROGRESS AND ACHIEVEMENTS IN FY 2004

Outcome 1.1.1: Enable prediction of polar and global stratospheric ozone recovery (amount and timing) to within 25% by 2014.

This year, space-based, airborne, balloon-borne, and ground-based measurements, coupled with advanced computer modeling, significantly improved scientists' predictions of ozone loss and recovery in Earth's polar regions. New data also helped NASA researchers better understand mass and ozone exchange between the stratosphere and troposphere, helping them improve modeling of ozone distribution, sources, and sinks (reservoirs of ozone-depleting chemicals). Researchers determined that stratospheric cooling associated with global warming could hasten global ozone recovery due to the way temperature affects the rates of some ozone loss. This same cooling could lead to more severe seasonal Arctic ozone losses, and delay polar ozone recovery, because increased abundances of polar stratospheric clouds activate the chemicals responsible for ozone loss.

Outcome 1.1.2: Predict the global distribution of tropospheric ozone and the background concentration in continental near-surface air to within 25% by 2014.

NASA launched the Aura spacecraft on July 15, 2004 and Aura has already delivered new data that will advance the models required for the prediction of global tropospheric ozone. In addition, the Transport and Chemical Evolution of the Pacific mission, which used a combination of airborne and satellite instruments, produced two special issues of the Journal of Geophysical Research: Atmospheres documenting the increased understanding of how emissions from Asia affect global tropospheric ozone.

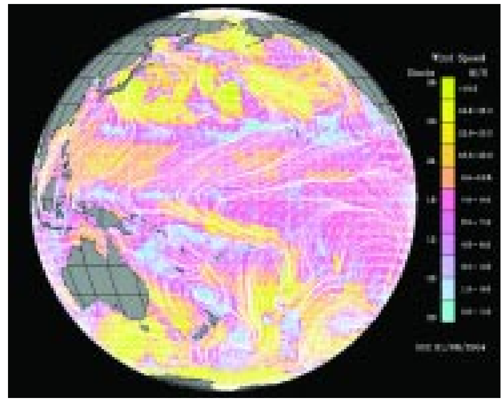


Figure 65: This image uses data from the QuikSCAT instrument on SeaWinds to show winds on the surface of the Pacific Ocean on January 8, 2004. NASA scientists are using satellite data to create three-dimensional models, which include temperature, salinity, and current, that help them forecast ocean conditions up to three days in advance.

Outcome 1.1.3: Enable extension of air quality forecasts for ozone and aerosols from 24 to 72 hours by 2010.

Accurate air quality forecasts require accurate emissions data. A combination of data from satellite missions and aircraft campaigns have revealed errors in emissions inventories for tropospheric aerosols and precursor gases for tropospheric ozone. NASA is using this current data to correct these inventories.

Outcome 1.1.4: Use satellite data to help enable decreased hurricane landfall uncertainty from +/- 400 km to +/- 100 km in the three-day forecasts by 2010.

NASA researchers are making significant progress in their ability to forecast hurricane landfall. This year, using case studies, researchers demonstrated improved five-day storm track prediction and precipitation forecasts for hurricanes Bonnie and Floyd using data from the Tropical Rainfall Measuring Mission satellite's Microwave Imager and Special Sensor Microwave Imager, which are part of the Goddard Earth Observing System global data assimilation system. Additional studies by Florida State University and Langley Research Center investigators demonstrated that remotely sensed humidity profiles from suborbital platforms could improve three-day hurricane track forecasts by 100 kilometers over forecasts using traditional aircraft-based information.

Outcome 1.1.5: Use satellite data to help extend more accurate regional weather forecasting from 3 days to 5 days by 2010.

NASA developed the capability to integrate Atmospheric Infrared Sounder temperature and moisture profiles into the National Oceanic and Atmospheric Administration's (NOAA's) Forecast System Laboratory Local Analysis and Prediction System. Researchers used profiles generated over land and water at 45-kilometer resolution to initialize the Pennsylvania State University/ National Center for Atmospheric Research MM5 model system. Preliminary experiments showed that the profiles had a positive impact on subsequent forecasts; forecasts of temperature and moisture were extended 17 hours, as determined by NOAA's National Weather Service network. Similarly, data from the Tropical Rainfall Measuring Mission Microwave Imager had a positive impact on Atlantic tropical storm intensification forecasts; they were extended to 72 hours when introduced into an experimental version of NOAA's Statistical Hurricane Prediction Scheme model.

Outcome 1.1.6: Develop projections of future atmospheric concentrations of carbon dioxide and methane for 10–100 years into the future with improvements in confidence of >50% by 2014.

Researchers compared satellite observations of fires, weather, and vegetation characteristics against measurements of atmospheric carbon dioxide and methane. The results revealed higher fire emissions during hotter and drier El Niño years. Fires cause most of the increases in atmospheric carbon dioxide and methane. Scientists are modifying their models to incorporate this new understanding of mechanisms controlling annual variations in carbon emissions. These modifications will directly improve the capability for projecting future atmospheric carbon dioxide and methane concentrations.

Outcome 1.1.7: By 2014, develop in partnership with other agencies, credible ecological forecasts that project the sensitivities of terrestrial and aquatic ecosystems to global environmental changes for resource management and policy-related decision-making.

NASA analyzed results from its Carnegie–Ames–Stanford Approach (CASA) model (developed by scientists from NASA's Ames Research Center, the Carnegie Institute, and Stanford University) and CASA–Carbon Query and Evaluation Support Tools, developed for use in the Invasive Species Forecasting System. The model also identified forest and agricultural sinks (reservoirs that absorb released carbon from another part of the carbon cycle) for atmospheric carbon dioxide. Through an Internet interface, researchers can now use the NASA CASA model and CASA–Carbon Query and Evaluation Support Tools to support ecosystem decisions and carbon management applications.

Outcome 1.1.8: Report changes in global land cover, productivity, and carbon inventories with accuracies sufficient for use in the food industry, in evaluating resource management activities, and in verifying inventories of carbon emissions and storage.

The world's oceans, soil, and above-ground biomass absorb approximately 50 percent of the carbon emitted into the atmosphere each year, providing a natural—and crucial—way to manage atmospheric carbon dioxide. NASA analyzed satellite records of worldwide surface seawater chlorophyll concentrations, and the results show that chlorophyll production in the North Pacific and North Atlantic gyres (circular ocean currents) vary from season to season, but generally expanded from 1996 through 2003. Little change occurred in the South Pacific, South Atlantic, and southern Indian Ocean gyres. In addition, the Large Scale Biosphere–Atmosphere Experiment in Amazonia provided data on current land cover changes and its effect on the carbon balance in the Amazon. These results are helping scientists improve their estimates of global ocean carbon storage dynamics, verify forest inventories, and update estimates of tropical carbon emissions dynamics.

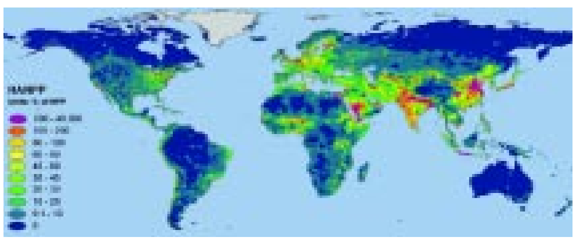


Figure 66: This figure shows human appropriation of net primary production (NPP) as a percentage of the local NPP. The map provides insight into the percent of plant resource used by people in an area compared to the amount of plant resource that is actually available locally. The data used for this map, created as part of a project between NASA and the World Wildlife Fund, was processed by NASA but derived from the National Oceanic and Atmospheric Administration's Polar Orbiting Environmental Satellites.

Outcome 1.1.9: Enable development of seasonal precipitation forecasts with >75% accuracy by 2014.

Through the North American Land Data Assimilation System, researchers now can model the land surface of the continental United States to within 1/8th-degree resolution for a period of 25 years. They achieved this high degree of accuracy by using multiple models. The Global Land Data Assimilation System project and Global Soil Wetness Project II have extended this work to include the entire globe. The products of these projects were used in the Global Land–Atmosphere Coupling Experiment, which indicated areas around the world where having soil moisture information would improve researchers' ability to predict precipitation. Scientists also used recent NASA data from the Gravity Recovery and Climate Experiment satellite to provide new information about large-scale (more than 500,000 square-kilometer) changes in total water storage. They are integrating this data with seasonal prediction systems to reduce errors in forecasting seasonal precipitation.

Outcome 1.1.10: Improve estimates of the global water and energy cycles by 2012 to enable balancing of the global and regional water and energy budgets to within 10%.

The Coordinated Enhanced Observing Period, an international program to establish an integrated global observing system for Earth's water cycle, is using NASA's Global Land Data Assimilation System data to identify gaps in observations and understanding that prevent researchers from developing better models of the water and energy cycle budget (the total amount of water and energy that cycles between land, water, and the atmosphere). In addition, NASA's Land Information System project developed a one-kilometer-resolution global land surface modeling platform that eventually will enable researchers to validate (and improve their ability to identify) deficiencies in global water and energy cycle budget balances and to improve estimates of local, regional, and global budgets to below 10 percent.

Outcome 1.1.11: Reduce uncertainty in global sea level change projections by 50% by the year 2014, and include regional estimates of deviation from global mean.

This year, scientists successfully modeled the state of the ocean through NASA's Estimating the Circulation and Climate of the Ocean project. Comparisons of data from different models show that scientists are making significant progress in both their overall understanding of the physical state of the ocean and their ability to predict ocean changes. This project is now running a 10-year model of global ocean circulation at one-quarter degree resolution.

Outcome 1.1.12: Enable 10-year or longer climate forecasts by the year 2014 with a national climate modeling framework capable of supporting policy decision-making at regional levels.

This year, NASA developed new Atmosphere-Ocean Global Climate Models that make contributions to the upcoming third assessment, reported in the Intergovernmental Panel on Climate Change, a group that assesses scientific, technical, and socio-economic information relevant for the understanding of climate change. NASA scientists will analyze assessment runs and compare them to results from the Geophysical Fluid Dynamics Laboratory and the National Center for Atmospheric Research climate runs. These activities will set the stage for multi-agency collaborative development, testing, and assimilation of data for process validation. This is the first archive of global cloud systems developed in a cloud object database with attendant atmospheric state parameters. It is a key resource for testing cloud models used in climate systems models.

Outcome 1.1.13: Enable 30-day volcanic eruption forecasts with > 50% confidence by 2014.

This year, NASA used geodetic global positioning systems to measure volcanic inflation and earthquake fault motion to validate the development of space geodetic technology, hardware, algorithms, and scientific research of the past 20 years. The Gravity Recovery and Climate Experiment (GRACE) measured the accumulation of stress along convergent plate boundaries that has lead to some of the largest earthquakes on the Earth's surface. GRACE data provided the first confirmation that time variable gravity could be measured at high resolution far exceeding any equivalent land surface measurements, and quantitatively estimated monthly water accumulation within the South American Amazon and Orinoco river basins. GRACE data and related algorithms have improved the ability to resolve the mass flux dynamics of the Earth System including the ultimate measurement of regional strain accumulation at plate boundaries. This activity was part of NASA's participation in "Restless Planet," an initiative of the multi-agency EarthScope program that applies observational, analytical, and telecommunications technologies to investigate the structure and evolution of the North American continent and the physical processes controlling earthquakes and volcanic eruptions. In addition, NASA accumulated over 200 Interferometric Synthetic Aperture Radar interferograms to track the inflationary cycle of Mount Etna over the past 13 years. (During inflationary cycles, the volcanic edifice bulges and grows in reaction to the build-up of lava and gas inside the volcano.) The study included an analysis of crustal failure along the flanks of Mount Etna. Understanding the failure points of volcanoes under inflationary pressure leads to predicting volcanic eruption.

The Shuttle Radar Topography Mission, a collaboration between NASA, the National Geospatial Intelligence Agency, and the German and Italian Space Agencies, provided high-resolution topography to help scientists analyze high-resolution imaging of regional geologic structures, such as faults and volcanoes. Data from this mission also helped scientists analyze other geophysical data sets. Data released in July 2004 provided the research community with the first complete Shuttle Radar Topography Mission 90-meter-resolution database. The mission was 99.9 percent successful in providing the first uniform-accuracy topographic maps of land masses within 60 degrees of the equator with a vertical accuracy of better than 10 meters (approximately 33 feet). This data helps scientists understand the physics of earthquakes, volcanoes, and landslides within the North American plate.

NASA also began developing an airborne capability that will equip an uncrewed airborne vehicle with a synthetic aperture radar that can detect geophysical changes related to volcanic eruptions.

Outcome 1.1.14: Enable estimation of earthquake likelihood in North American plate boundaries with > 50% confidence by 2014.

This year, NASA corrected the Rundle-Tiampo statistical prediction model developed in 2002 by Kristy Tiampo of the University of West Ontario, Canada, and John Rundle of the University of California. The Rundle-Tiampo model is used to pinpoint earthquake locations in southern California for 2000-2010. NASA researchers used their improved model including detailed interferometric synthetic aperture radar measurements, to re-analyze data previously analyzed by Rundle's model and expanded the analysis to all of California. The Rundle-Tiampo forecast model, using data from NASA's Interferometric Synthetic Aperture Radar instrument, and results from NASA-Jet Propulsion Laboratory's QuakeSim project, made unprecedented forecasts of the locations for 15 of the last 16 tremors, with magnitudes greater than 5.0 on the Richter scale, since January 2000, and has successfully pinpointed the location of nearly every major tremor in the Southern California region for the last four years.

Performance Measures for Objective 1.1		2004 Rating	Past Years' Performance Measures and Ratings	2003	2002	2001
Outcome 1.1.1	Enable prediction of polar and global stratospheric ozone recovery (amount and timing) to within 25% by 2014.	green		Outcomes originated in FY 2004		
APG 4ESS7	Atmospheric Composition—Integrate high latitude satellite, suborbital, and ground based observations, coupled with laboratory studies and model calculations to assess the potential for future ozone depletion in the arctic, and characterize the properties and distributions of various types of clouds and aerosols as they relate to the extinction of solar radiation in the atmosphere. Progress toward achieving outcomes will be validated by external review. (This APG applies to Outcomes 1.1.1, 1.1.2, and 1.1.3.)	green		3Y22 green	2Y22 green	none
				3Y4 yellow	2Y4 yellow	none
Outcome 1.1.2	Predict the global distribution of tropospheric ozone and the background concentration in continental near-surface air to within 25% by 2014.	green		Outcomes originated in FY 2004		
APG 4ESS7	Atmospheric Composition—Integrate high latitude satellite, suborbital, and ground based observations, coupled with laboratory studies and model calculations to assess the potential for future ozone depletion in the arctic, and characterize the properties and distributions of various types of clouds and aerosols as they relate to the extinction of solar radiation in the atmosphere. Progress toward achieving outcomes will be validated by external review. (This APG applies to Outcomes 1.1.1, 1.1.2, and 1.1.3.)	green		none	none	none
Outcome 1.1.3	Enable extension of air quality forecasts for ozone and aerosols from 24 to 72 hours by 2010.	green		Outcomes originated in FY 2004		
APG 4ESS7	Atmospheric Composition—Integrate high latitude satellite, suborbital, and ground based observations, coupled with laboratory studies and model calculations to assess the potential for future ozone depletion in the arctic, and characterize the properties and distributions of various types of clouds and aerosols as they relate to the extinction of solar radiation in the atmosphere. Progress toward achieving outcomes will be validated by external review. (This APG applies to Outcomes 1.1.1, 1.1.2, and 1.1.3.)	green		none	none	none
Outcome 1.1.4	Use satellite data to help enable decreased hurricane landfall uncertainty from +/- 400 km to +/- 100 km in the three-day forecasts by 2010.	green		Outcomes originated in FY 2004		
APG 4ESS8	Weather—Improve predictive capabilities of regional models using satellite-derived localized temperature and moisture profiles and ensemble modeling. Progress toward achieving outcomes will be validated by external review. (This APG applies to Outcomes 1.1.4 and 1.1.5.)	green		none	none	none
Outcome 1.1.5	Use satellite data to help extend more accurate regional weather forecasting from 3 days to 5 days by 2010.	green		Outcomes originated in FY 2004		
APG 4ESS8	Weather—Improve predictive capabilities of regional models using satellite-derived localized temperature and moisture profiles and ensemble modeling. Progress toward achieving outcomes will be validated by external review. (This APG applies to Outcomes 1.1.4 and 1.1.5.)	green		3Y19 green	2Y19 green	none
Outcome 1.1.6	Develop projections of future atmospheric concentrations of carbon dioxide and methane for 10-100 years into the future with improvements in confidence of >50% by 2014.	green		Outcomes originated in FY 2004		
APG 4ESS9	Carbon Cycles, Ecosystems, and Biogeochemistry—Reduce land cover errors in ecosystem and carbon cycle models, and quantify global terrestrial and marine primary productivity and its interannual variability. Progress toward achieving outcomes will be validated by external review. (This APG applies to Outcomes 1.1.6, 1.1.7, and 1.1.8.)	green		3Y23 green	none	none
Outcome 1.1.7	By 2014, develop in partnership with other agencies, credible ecological forecasts that project the sensitivities of terrestrial and aquatic ecosystems to global environmental changes for resource management and policy-related decision-making.	green		Outcomes originated in FY 2004		
APG 4ESS9	Carbon Cycles, Ecosystems, and Biogeochemistry—Reduce land cover errors in ecosystem and carbon cycle models, and quantify global terrestrial and marine primary productivity and its interannual variability. Progress toward achieving outcomes will be validated by external review. (This APG applies to Outcomes 1.1.6, 1.1.7, and 1.1.8.)	green		3Y3 green	2Y3 green	none

	Performance Measures for Objective 1.1	2004 Rating	Past Years' Performance Measures and Ratings	2003	2002	2001
Outcome 1.1.8	Report changes in global land cover, productivity, and carbon inventories with accuracies sufficient for use in the food industry, in evaluating resource management activities, and in verifying inventories of carbon emissions and storage.	green		Outcomes originated in FY 2004		
APG 4ESS9	Carbon Cycles, Ecosystems, and Biogeochemistry—Reduce land cover errors in ecosystem and carbon cycle models, and quantify global terrestrial and marine primary productivity and its interannual variability. Progress toward achieving outcomes will be validated by external review. (This APG applies to Outcomes 1.1.6, 1.1.7, and 1.1.8.)	green		3Y17 green 3Y8 green	2Y17 green 2Y8 green	none none
Outcome 1.1.9	Enable development of seasonal precipitation forecasts with >75% accuracy by 2014.	green		Outcomes originated in FY 2004		
APG 4ESS10	Water and Energy Cycle—Enhance land surface modeling efforts, which will lead to improved estimates of soil moisture and run-off. Progress toward achieving outcomes will be validated by external review. (This APG applies to Outcomes 1.1.9 and 1.1.10.)	green		3Y1 green	2Y1 yellow	1Y5 green
Outcome 1.1.10	Improve estimates of the global water and energy cycles by 2012 to enable balancing of the global and regional water and energy budgets to within 10%.	green		Outcomes originated in FY 2004		
APG 4ESS10	Water and Energy Cycle—Enhance land surface modeling efforts, which will lead to improved estimates of soil moisture and run-off. Progress toward achieving outcomes will be validated by external review. (This APG applies to Outcomes 1.1.9 and 1.1.10.)	green		none	none	none
Outcome 1.1.11	Reduce uncertainty in global sea level change projections by 50% by the year 2014, and include regional estimates of deviation from global mean.	green		Outcomes originated in FY 2004		
APG 4ESS11	Climate, Variability and Change—Assimilate satellite and in situ observations into a variety of ocean, atmosphere, and ice models for purposes of state estimation; provide experimental predictions on a variety of climatological timescales; and determine the plausibility of these predictions using validation strategies. Progress toward achieving outcomes will be validated by external review. (This APG applies to Outcomes 1.1.11 and 1.1.12.)	green		3Y18 green 3Y5 green 3Y14 green	2Y18 green 2Y5 green 2Y14 green	none none none
Outcome 1.1.12	Enable 10-year or longer climate forecasts by the year 2014 with a national climate modeling framework capable of supporting policy decision-making at regional levels.	green		Outcomes originated in FY 2004		
APG 4ESS11	Climate, Variability and Change—Assimilate satellite and in situ observations into a variety of ocean, atmosphere, and ice models for purposes of state estimation; provide experimental predictions on a variety of climatological timescales; and determine the plausibility of these predictions using validation strategies. Progress toward achieving outcomes will be validated by external review. (This APG applies to Outcomes 1.1.11 and 1.1.12.)	green		3Y10 green 3Y21 green	2Y10 green 2Y21 green	none none
Outcome 1.1.13	Enable 30-day volcanic eruption forecasts with >50% confidence by 2014.	green		Outcomes originated in FY 2004		
APG 4ESS12	Earth Surface and Interior Structure—Advance understanding of surface change through improved geodetic reference frame, estimates of mass flux from satellite observations of Earth's gravitational and magnetic fields, and airborne and spaceborne observations of surface height and deformation. Progress toward achieving outcomes will be validated by external review. (This APG applies to Outcomes 1.1.13 and 1.1.14.)	green		none	none	none
Outcome 1.1.14	Enable estimation of earthquake likelihood in North American plate boundaries with >50% confidence by 2014.	green		Outcomes originated in FY 2004		
APG 4ESS12	Earth Surface and Interior Structure—Advance understanding of surface change through improved geodetic reference frame, estimates of mass flux from satellite observations of Earth's gravitational and magnetic fields, and airborne and spaceborne observations of surface height and deformation. Progress toward achieving outcomes will be validated by external review. (This APG applies to Outcomes 1.1.13 and 1.1.14.)	green		3Y6 green	2Y6 green	none

Goal 1 Understand the Earth system and apply Earth system science to improve prediction of climate, weather, and natural hazards.

OBJECTIVE 1.2

Expand and accelerate the realization of economic and societal benefits from Earth science, information, and technology.

WHY PURSUE OBJECTIVE 1.2?

Naturally occurring and human-induced changes in Earth's system have profound consequences for the Nation and the world. NASA's Earth observing capabilities and scientific research, coupled with those from its partners, are helping society manage risks and take advantage of opportunities resulting from Earth system changes. Through improved predictions of weather, climate, and natural hazards, NASA Earth science research helps the United States and the world make sound, scientifically based decisions in areas such as agriculture, homeland security, ecology, water management, public health, and aviation safety.

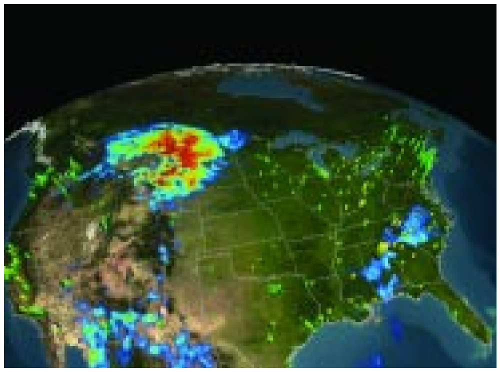


Figure 67: Air quality data from the Environmental Protection Agency, shown as three-dimensional spikes on this map of North America, is expanded and enhanced by data from the Moderate Resolution Imaging Spectroradiometer on the Terra and Aqua satellites, shown as the color overlay. In this image, green indicates healthy air while red indicates unhealthy air.

By working with Federal agency partners, NASA improves essential public services like tracking hurricanes, assessing crop health and productivity, evaluating forest fire risks, ensuring aviation safety, improving energy forecasts, and determining the potential for the climate-driven spread of infectious disease. NASA's Earth-observing systems and Earth science models advance researchers' ability to understand and protect Earth, its resources, and its diverse and precious life.

NASA'S PROGRESS AND ACHIEVEMENTS IN FY 2004

Outcome 1.2.1: By 2012, benchmark the assimilation of observations (geophysical parameters, climate data records) provided from 20 of the 80 remote sensing systems deployed on the flotilla of 18-22 NASA Earth observation research satellites.

This year, NASA and the Environmental Protection Agency's Office of Air Quality Planning and Standards partnered to create a prototype Web-based pollution forecast tool to improve the Environmental Protection Agency's air quality index forecasts. The tool uses data from NASA's Moderate Resolution Imaging Spectroradiometer aboard the Terra and Aqua satellites to forecast air quality and pollution. The Environmental Protection Agency recently integrated the tool into its AIRNow Forecaster Training Workshops, which reach over 200 air quality forecasting professionals.

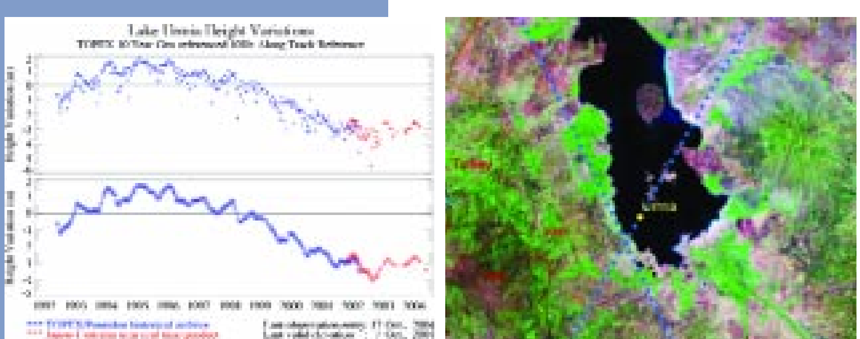


Figure 68: The chart at left shows the relative lake height variations for Lake Urmia, Iran, computed from TOPEX/POSEIDON and Jason-1 altimetry data. It shows that water height has declined steadily since the mid-1990s. The map on the right, taken by Landsat-5, shows the path (marked with blue dots) taken by the Jason-1 spacecraft. Information on this and other lakes and reservoirs around the worlld are available on the U.S. Department of Agriculture Foreign Agricultural Service's Crop Explorer Web site, at www.pecad.fas.usda.gov/cropexplorer/global_reservoir/.

Using radar altimetry data from NASA's TOPEX/Poseidon and Jason-1 satellites, researchers from NASA, the U.S. Department of Agriculture's Foreign Agricultural Service, and the University of Maryland estimated reservoir height and water volume in approximately 100 lakes and reservoirs around the world's major agricultural regions to locate regional droughts and improve crop production estimates for irrigated regions located downstream. The Foreign Agriculture Service also uses NASA-produced water availability information to make decisions about global agricultural estimates. In a related study, students in NASA's Digital Earth Virtual Environment and Learning Outreach Project program applied NASA research results in testing several new water and energy decision-support tools.

Outcome 1.2.2: By 2012, benchmark the assimilation of 5 specific types of predictions resulting from Earth Science Model Framework (ESMF) of 22 NASA Earth system science models.

Supported by Federal, private sector, and academic partnerships, NASA continues to make strides toward this Outcome. This year, NASA catalogued the Earth System Model Data Framework climate and weather prediction models that use data and observations from NASA research satellites. The Agency also evaluated data from its Atmospheric Infrared Sounder temperature and moisture profiles for use in disaster management and aviation applications, including National Oceanic and Atmospheric Administration's Statistical Hurricane Prediction Scheme model. In addition, with the help of the U.S. Geological Survey and the U.S. Department of Agriculture, NASA evaluated results from its Carnegie–Ames–Stanford Approach (CASA) model (developed by scientists from NASA's Ames Research Center, the Carnegie Institute, and Stanford University) and CASA–Carbon Query and Evaluation Support Tools (CQUEST) for use in the Invasive Species Forecasting System that provides decision support for ecosystem and carbon management applications. Using vegetation data from NASA's Moderate Resolution Imaging Spectroradiometer aboard the Terra and Aqua satellites, the CASA model predicts photosynthesis rates, the amount of vegetation and living organisms within a unit area, and "litterfall," which is organic matter from the biosphere that moves to litter layer in soil. CQUEST allows Web users to display, manipulate, and save ecosystem model estimates of carbon sinks (a reservoir that absorbs and stores carbon dioxide from the atmosphere) and carbon dioxide fluctuations in agricultural and forest ecosystems for locations anywhere in the United States.

Outcome 1.2.3: By 2012, benchmark the assimilation of observations and predictions resulting from NASA Earth Science research in 8-10 decision support systems serving national priorities and the missions of Federal agencies.

NASA partnered with a number of Federal agencies to produce decision support systems using NASA Earth science research. The table below highlights some of the ongoing partnerships and decision support systems currently in development.

Partner Agency	Activity
U.S. Department of Agriculture	Global crop production assessment NASA Carnegie–Ames–Stanford Approach (CASA) model and CASA–Carbon Query and Evaluation Support Tool (CQUEST)
Environmental Protection Agency	AirNow and Air Quality Forecasting decision support tools
Federal Aviation Administration	Advanced Weather Interactive Processing System
U.S. Geological Survey	Invasive Species Forecasting System
Federal Emergency Management Agency	HAZUS–US tool, a National Flood Loss Estimation Model
U.S. Agency for International Development (AID) and Central American Commission for Environment and Development	SERVIR tool, a regional visualization and monitoring system that will assist the seven nations of Central America in developing a Mesoamerican Biological Corridor extending from southern Mexico to the Colombian border
Department of Homeland Security	International Materials Assessment and Application Centre
Centers for Disease Control	California Environmental Public Health Tracking Network
U.S. Department of the Interior	RiverWare and Agricultural Water Resources Decision Support tools
National Oceanic and Atmospheric Administration	Coral Reef Early Warning System tool

Performance Measures for Objective 1.2		2004 Rating	Past Years' Performance Measures and Ratings	2003	2002	2001
Outcome 1.2.1	By 2012, benchmark the assimilation of observations (geophysical parameters, climate data records) provided from 20 of the 80 remote sensing systems deployed on the flotilla of 18–22 NASA Earth observation research satellites.	green		Outcomes originated in FY 2004		
Outcome 1.2.2	By 2012, benchmark the assimilation of 5 specific types of predictions resulting from Earth Science Model Framework (ESMF) of 22 NASA Earth system science models.	green		Outcomes originated in FY 2004		
Outcome 1.2.3	By 2012, benchmark the assimilation of observations and predictions resulting from NASA Earth Science research in 8–10 decision support systems serving national priorities and the missions of federal agencies.	green		Outcomes originated in FY 2004		
APG 4ESA1	National applications—Benchmark measurable enhancements to at least 2 national decision support systems using NASA results, including the use of optical depth derived from MODIS data into the Air Quality Index provided by EPA and the use of ocean height derived from Topex and Jason missions into reservoir monitoring tools with USDA. (This APG applies to Outcomes 1.2.1 and 1.2.3.)	green		3Y24 green	2Y23 green	1Y14 green
APG 4ESA2	Cross Cutting Solutions—Expand DEVELOP (Digital Earth Virtual Environment and Learning Outreach Project) workforce development program to 2-4 additional states and benchmark the use of NASA research results for water and energy decision support tools. (This APG applies to Outcomes 1.2.1, 1.2.2, and 1.2.3.)	green		none	none	none
APG 4ESA3	Cross Cutting Solutions—Competitively select at least 5 solutions projects for the Research, Education, Applications Solutions Network (REASoN) program to serve national applications through projects that support agriculture, public health and water quality decision support tools. (This APG applies to Outcomes 1.2.1, 1.2.2, and 1.2.3.)	green		none	none	none
APG 4ESA4	Cross Cut Solutions—Verify and validate at least two commercial remote sensing sources/products for Earth science research including DigitalGlobe Quicksat and OrbImage Overview-3 high resolutions optical imagery. (This APG also applies to Outcome 1.2.1.)	green		none	none	none

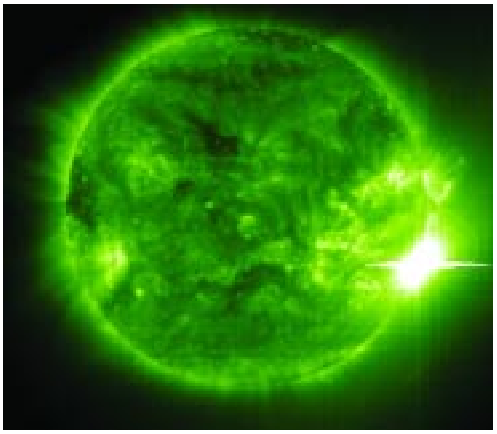
Goal 1 Understand the Earth system and apply Earth system science to improve prediction of climate, weather, and natural hazards.

OBJECTIVE 1.3

Understand the origins and societal impacts of variability in the Sun–Earth connection.

WHY PURSUE OBJECTIVE 1.3?

Life on Earth prospers in a biosphere sustained by energy from the Sun. Changes in the Sun can cause long- and short-term changes on Earth, affecting global climate, disrupting communication and navigation systems, and posing a radiation danger for humans in space.



Credit: NASA/ESA/EIT Consortium

Figure 69: A giant sunspot region lashed out with a huge solar flare (visible on the right side of the Sun) followed by a large coronal mass ejection on November 4, 2003, captured in this extreme ultraviolet image taken by the Solar and Heliospheric Observatory. The energetic particle radiation caused substantial radio interference on Earth.

NASA seeks to develop the scientific understanding necessary to predict and mitigate the effects of solar changes. With help from its partners, NASA forecasts solar activity, measures the radiation that bombards Earth, and studies Earth's atmosphere and magnetic field that shields life from this radiation. NASA is probing the links between the Sun's variable layers and Earth's protective layers. With NASA's help, researchers are beginning to understand the physics of space weather, the diverse array of dynamic and interconnected phenomena that affect both life and society. NASA also is characterizing the radiation environment to improve spacecraft designs and to protect astronauts as they venture beyond Earth.

NASA'S PROGRESS AND ACHIEVEMENTS IN FY 2004

The Space Science Advisory Committee, an external advisory board, reviewed the progress of Outcomes 1.3.1, 1.3.2, and 1.3.3 and determined that NASA successfully demonstrated progress in all three Outcomes during FY 2004.

Outcome 1.3.1: Develop the capability to predict solar activity and the evolution of solar disturbances as they propagate in the heliosphere and affect the Earth.

This year, The Advanced Composition Explorer spacecraft measured the effects of a coronal mass ejection that produced solar wind speeds in excess of 1100 miles-per-second, the fastest ever directly observed. (A coronal mass ejection occurs when the Sun ejects huge bubbles of gas over the course of several hours, often disrupting the flow of the solar wind and producing disturbances on Earth and throughout the solar system.) Shock waves from the coronal mass ejection produced and heated the fast winds to temperatures greater than 10 million degrees, the hottest ever recorded in the solar wind. Using observations from the Solar and Heliospheric Observatory, researchers confirmed the theory that coronal mass ejections begin as slow eruptions in which the magnetic fields tethering the material to the Sun become stretched and break, allowing the coronal mass ejection to rapidly accelerate and heat. Fast coronal mass ejections cause some of the most violent space weather, including energetic particles hazardous to astronauts, so studying such events helps NASA predict and prepare for extreme space weather that could pose a threat to astronauts in space or technology on Earth.

Supported by the Living with a Star Targeted Research and Technology Program, researchers developed a solar cycle prediction model based on new discoveries about the Sun's magnetic field. Solar cycles usually last about 11 years. The model explains the unusual behavior observed in the last solar cycle and predicts a 6 to 12 month delay for the onset of the next cycle. In addition, NASA scientists tested techniques to forecast interplanetary space weather during a fortuitous alignment of planets while the Cassini spacecraft flew by Jupiter. The test traced solar wind surge from Earth to Jupiter, and the close alignment enabled researchers to predict conditions at Jupiter with impressive accuracy (1 day advance notice for the arrival time of a surge with 5-10 day duration).

Outcome 1.3.2: Specify and enable prediction of changes to the Earth's radiation environment, ionosphere, and upper atmosphere.

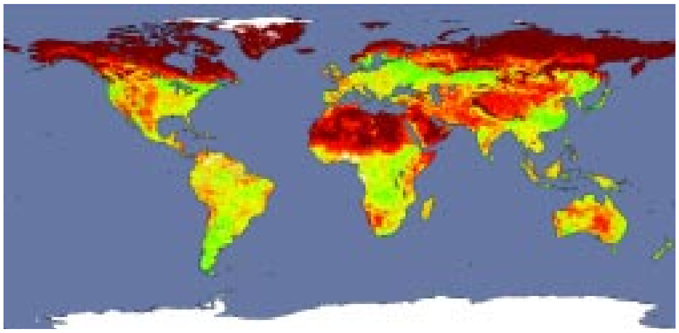
This year, the Solar, Anomalous, and Magnetospheric Particle Explorer completed a 12-year survey of the radiation particle environment of low Earth orbit. Scientists will use the resulting data to help them specify galactic rays, anomalous cosmic rays, and other solar energetic particle events in which high-energy particles are ejected from the Sun. Other Studies of solar energetic particle events by the Solar, Anomalous, and Magnetospheric Particle Explorer and the Advanced Composition Explorer revealed that partially ionized heavier particles, such as iron, escape from solar events more easily. These results and measurements demonstrate the need to improve continuously the engineering models used for predicting the range of radiation effects that can be expected over the lifetime of a space mission. This research also will help scientists define future tests leading to improved prediction of hazardous space radiation.

The Thermosphere, Ionosphere, Mesosphere, Energetics, and Dynamics satellite, designed to study the effects of the Sun on Earth's atmosphere, captured for the first time satellite-based temperature measurements covering both day and night from 68 to 74 miles above Earth. Using data from the satellite, scientists developed a global map of ionospheric plasma depletions and electron density profiles that will be incorporated into the International Reference Ionosphere model, an international project sponsored by the Committee on Space Research and the International Union of Radio Science to characterize the ionosphere, including electron density, electron temperature, ion temperature, and ion composition.

Outcome 1.3.3: Understand the role of solar variability in driving space climate and global change in Earth's atmosphere.

NASA's fleet of science satellites traced the flow of energy from the Sun, through interplanetary space, to its dissipation in Earth's atmosphere during massive increases in solar flares and coronal mass ejections. Large, dark sunspots caused remarkable decreases in solar radiative output, better known as sunlight, whereas remendous solar flares caused increases. The project captured immediate and delayed response of the Sun–Earth system on a global scale. From this, scientists are gaining new perspectives on Sun–Earth system plasma, dynamics, and chemical processes.

By monitoring the glow of light reflected from Earth onto the moon's dark side, the Living with a Star Targeted Research Technology Program showed that the Earth's average albedo (reflectivity) varies considerably over time. During the 1980s and 1990s, the Earth bounced less sunlight out to space, but the trend reversed during the past three years. Although the reasons for these trends are not fully understood, scientists believe that the decrease in reflected sunlight was related to an increase in mean global surface temperatures, and the recent increases to changes in cloud properties. The research offers evidence that Earth's average albedo varies considerably from year to year, and from decade to decade. Scientists must conduct more research into solar variability and climate change before they can confidently model future albedo changes.



Credit: C. Schaat, Boston University

Figure 70: The MODIS instrument, flying aboard NASA's Terra and Aqua satellites, measures how much solar radiation is reflected by the Earth's surface over the entire planet. Areas colored red show the most reflective regions; yellows and greens are intermediate; and blues and violets show relatively dark surfaces. White indicates no data was available, and no albedo data are provided over the oceans. This image was produced using data composited from April 7–22, 2002.

NASA's Scientific Ballooning Program launched the Solar Bolometric Imager and made the first precision broadband light images of the Sun. These spatially resolved absolute measurements of total solar irradiance will allow the sources of radiance to be understood and quantified separately clarifying the Sun's role in global climate change.

NASA's Theory Program simulations used solar irradiance data to model the solar rotational behavior of Earth's upper atmosphere and successfully predict and measure its effects on satellites.

Performance Measures for Objective 1.3		2004 Rating	Past Years' Performance Measures and Ratings	2003	2002	2001
Outcome 1.3.1	Develop the capability to predict solar activity and the evolution of solar disturbances as they propagate in the heliosphere and affect Earth.	green		Outcomes originated in FY 2004		
APG 4SEC8	Successfully demonstrate progress in developing the capability to predict solar activity and the evolution of solar disturbances as they propagate in the heliosphere and affect Earth. Progress towards achieving outcomes will be validated by external review.	green		3S7 green	2S7 green	none
Outcome 1.3.2	Specify and enable prediction of changes to Earth's radiation environment, ionosphere, and upper atmosphere.	green		Outcomes originated in FY 2004		
APG 4SEC9	Successfully demonstrate progress in specifying and enabling prediction of changes to Earth's radiation environment, ionosphere, and upper atmosphere. Progress towards achieving outcomes will be validated by external review.	green		3S8 green	2S8 green	1S11 green
Outcome 1.3.3	Understand the role of solar variability in driving space climate and global change in Earth's atmosphere.	blue		Outcomes originated in FY 2004		
APG 4SEC10	Successfully demonstrate progress in understanding the role of solar variability in driving space climate and global change in Earth's atmosphere. Progress towards achieving outcomes will be validated by external review.	blue		none	none	none

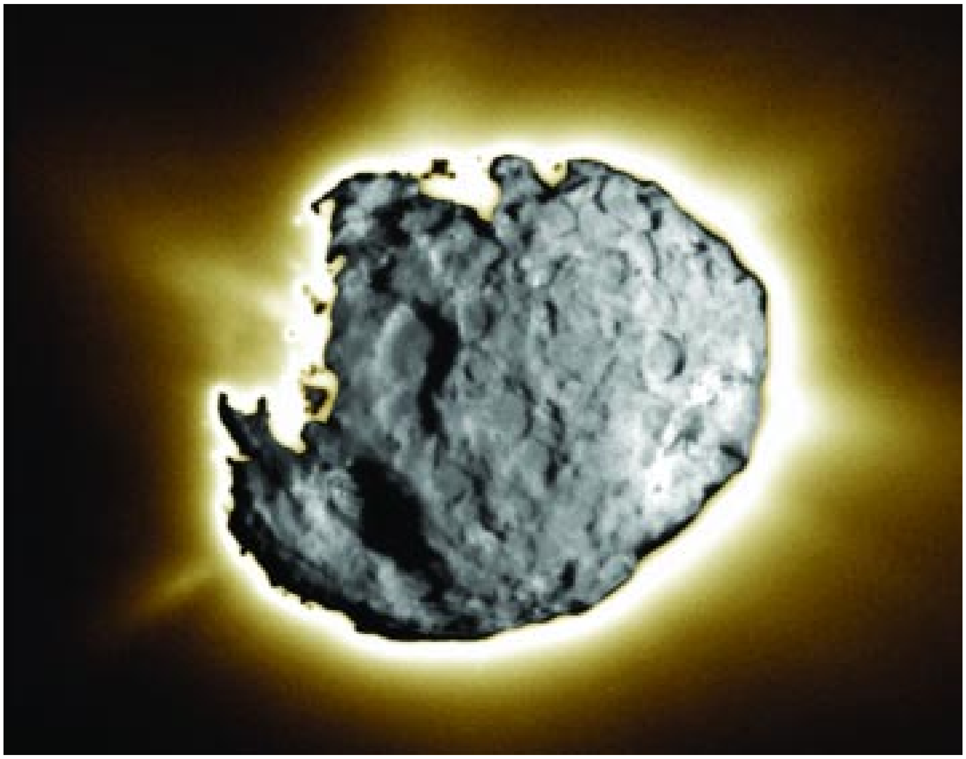
Goal 1 Understand the Earth system and apply Earth system science to improve prediction of climate, weather, and natural hazards.

OBJECTIVE 1.4

Catalog and understand potential impact hazards to Earth from space.

WHY PURSUE OBJECTIVE 1.4?

The solar system is filled with rocky and icy debris that orbits the Sun—"leftovers" created when the solar system was young. The vast majority of this debris harmlessly passes by Earth, but occasionally some debris collides with this planet, creating a cosmic impact. The effects of cosmic impacts on Earth were realized in the 1980s when scientists found indications that the impact of an asteroid, at least ten kilometers in diameter, had caused the climatic changes that led to the mass extinction of the dinosaurs. Scientists estimate that impacts by asteroids as small as one kilometer (more than six miles) in diameter could cause major global climate changes, even global devastation. An impact by a body as small as 100 meters (about 328 feet across) could cause major damage to an entire metropolitan area.



Credit: NASA JPL/Caltech

Figure 71: This composite image, taken by the Stardust spacecraft during its January 2, 2004, flyby of Comet Wild 2, shows a rocky, cratered surface surrounded by glowing jets of dust and gas that leave a trail millions of kilometers long.

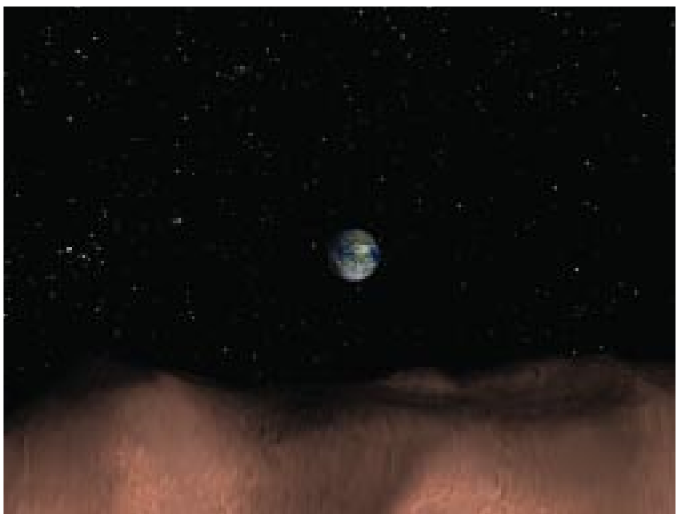
NASA is working toward an FY 2008 goal of identifying and inventorying at least 90 percent of all asteroids and comets larger than one kilometer in diameter that could come near Earth. By determining their orbits with sufficient accuracy, researchers could then predict whether any of them will pose a threat to Earth.

NASA'S PROGRESS AND ACHIEVEMENTS IN FY 2004

The Space Science Advisory Committee, an external advisory board, reviewed the progress of Outcomes 1.4.1 and 1.4.2 and determined that NASA successfully demonstrated progress in both Outcomes during FY 2004.

Outcome 1.4.1: By 2008, inventory at least 90 percent of asteroids and comets larger than 1 km in diameter that could come near Earth.

From May 2003 to May 2004, programs sponsored by NASA's Near Earth Object Observation Program discovered 68 new near-Earth asteroids with diameters estimated to be larger than 1 kilometer (approximately 0.6 miles) in diameter (out of a total of 481 near Earth asteroids of all sizes). Of these 68, NASA scientists found that 15 posed a potential collision threat to Earth sometime in the future—but not for at least 200 years. Scientists estimate that the total population of near-Earth asteroids with diameters larger than 1 kilometer is about 1100, and to date, they have identified 716.



Credit: NASA JPL/Caltech

Figure 72:Toutatis, a potato-shaped asteroid about 4.6 kilometers (3 miles) long, passed within 1,550,000 kilometers (963,000 miles) of Earth's center on September 29, 2004—approximately four times the distance of Earth to the Moon. This is the closest Earth approach this century for a known asteroid of this size. This artist's image depicts the asteroid's view of Earth during another close pass in November 1996.

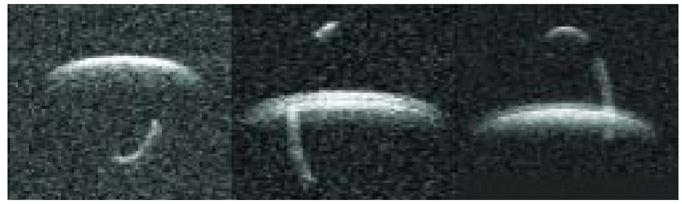


Figure 73: After eluding astronomers for decades, Dr. Jean-Luc Margot caught a glimpse of near-Earth asteroid 1999 KW4, also known as Hermes. His team discovered that the asteroid, shown here in a series of images taken by NASA's Goldstone radar system, is actually two objects: a component orbiting around a slightly larger mass.

Outcome 1.4.2: Determine the physical characteristics of comets and asteroids relevant to any threat they may pose to Earth.

The Goldstone and Arecibo Deep Space radar systems imaged the asteroid Hermes, a near-Earth, potentially hazardous asteroid that has not been seen since its discovery in 1937. The radar imaging revealed that Hermes actually consists of two objects held close to each other by their mutual gravitational attraction. Hermes, which has the most chaotic orbit of all near-Earth objects, can get as close to Earth as 608,000 kilometers (about 378,000 miles).

Scientists believe that comets, some of the oldest bodies in the solar system, are a major source of near-Earth asteroids. In January 2004, NASA's Stardust spacecraft rendezvoused with Wild 2, a comet passing relatively close to Earth, and returned images revealing that the nucleus of the comet is heavily cratered. This shows that the nucleus of Wild 2 consists of cohesive materials like ice, contradicting earlier beliefs that all comet nuclei are loosely bound aggregates of snow and dirt. The samples and images from Stardust will provide valuable insights into the building blocks of the early solar system and the characteristics of the small solar system bodies (e.g., asteroids) that were formed during this period.

Performance Measures for Objective 1.4		2004 Rating	Past Years' Performance Measures and Ratings	2003	2002	2001
Outcome 1.4.1	By 2008, inventory at least 90 percent of asteroids and comets larger than 1 km in diameter that could come near Earth.	green		Outcomes originated in FY 2004		
APG 4SSE10	Successfully demonstrate progress in determining the inventory and dynamics of bodies that may pose an impact hazard to Earth. Progress towards achieving outcomes will be validated by external review.	green		none	none	none
Outcome 1.4.2	Determine the physical characteristics of comets and asteroids relevant to any threat they may pose to Earth.	green		Outcomes originated in FY 2004		
APG 4SSE11	Successfully demonstrate progress in determining the physical characteristics of comets and asteroids relevant to any threat they may pose to Earth. Progress towards achieving outcomes will be validated by external review.	green		3S8 green	2S8 blue	none

OBJECTIVE 2.1

Decrease the aircraft fatal accident rate, reduce the vulnerability of the air transportation system to hostile threats, and mitigate the consequences of accidents and hostile acts.

WHY PURSUE OBJECTIVE 2.1?

Safety is one of NASA's core values. The Agency is committed to protecting the safety and health of the public, NASA's partners, NASA's people, and the assets that the public entrusts to the Agency. As part of this commitment, NASA is developing new and improved technologies that will ensure air transportation safety. Through advances in modeling and technology, NASA complements and extends improvements to operations, training, and technology made by the Federal Aviation Administration, the Department of Homeland Security, the Transportation Security Administration, and private industry.

Figure 74: NASA's Rogue Evaluation and Coordination Tool provides real-time information about aircraft that deviate from their expected flight path, allowing air traffic controllers to identify collision risks or potential terrorist threats.

NASA is creating new models for aviation safety management, including real-time identification and mitigation of risk at all levels, while continuing proactive work with other government agencies and industry to address issues impeding the improvement of aviation safety. The Agency's highest priority in this area is to research the most common causes of accidents. Other key areas of NASA research and technological development are flight during hazardous weather, controlled flight into terrain, air traffic management, human-error-induced accidents and incidents, and mechanical or software malfunctions.

NASA also is examining security concepts and technologies that could help stop terrorist acts. For example, NASA is using its unique resources to help prevent aircraft sabotage (the disruption of the command, navigation, and surveillance infrastructure) and to protect the transportation system from electronic viruses.

NASA'S PROGRESS AND ACHIEVEMENTS IN FY 2004

Outcome 2.1.1: By 2005, research, develop, and transfer technologies that will enable the reduction of the aviation fatal accident rate by 50% from the FY 1991–1996 average.

NASA completed a final integrated program assessment in September 2004. The assessment included: examining the projected impact of integrated research projects in NASA's Safety Program on aircraft accident rates; assessing the cost and benefits of proposed safety products; and reviewing changes in technical and implementation risks associated with aviation safety product development.

NASA also designed and manufactured full-scale engine components using alternative composite materials that will be tested for improved material integrity. And, the Agency completed simulation and flight-test evaluations of low-cost, forward-fit and retrofit Synthetic Vision technologies for general aviation aircraft in June 2004. During all of these tests and evaluations, engineers assessed the technical and operational performance of improved pilot situational awareness with regard to terrain portrayal, loss of control prevention, and display symbols. The results demonstrated the efficacy of Synthetic Vision's displays to eliminate a primary cause of general aviation accidents—controlled flight into terrain because the pilot could not see terrain changes—and greatly improve pilot situational awareness.

Outcome 2.1.2: By 2009, research, develop, and transfer technologies that will reduce the vulnerability exposure of the aircraft, and reduce the vulnerabilities of other components in the air transportation system.

NASA began implementing two new aviation security projects: System Vulnerability Detection and Aviation and Systems Vulnerability Mitigation. In June 2004, NASA completed a preliminary demonstration of the Rogue Evaluation And Coordination Tool, a security decision support program. Researchers evaluated the tool using a live traffic feed over eight hours for both the Fort Worth, Texas and Washington, D.C., air traffic control centers. The tool successfully detected aircraft that were deviating from their expected flight paths using four different methods. It also predicted incursions into restricted airspace, with countdown timers to entry into that airspace. These capabilities will enhance public safety by mitigating the potential for catastrophic harm that might otherwise result from a rogue aircraft.

Performance Measures for Objective 2.1		2004 Rating	Past Years' Performance Measures and Ratings	2003	2002	2001
Outcome 2.1.1	By 2005, research, develop, and transfer technologies that will enable the reduction of the aviation fatal accident rate by 50% from the FY 1991–1996 average.	green		Outcomes originated in FY 2004		
APG 4AT4	Utilizing results of component testing, simulations, and analyses, complete an integrated program assessment of the suite of aviation safety technologies to determine their synergistic effect on reducing the fatal accident rate.	green		3R1 yellow	2R1 green	none
APG 4AT5	Propulsion system malfunctions are cited in 25% of fatal accidents, with disk and/or fan blade component failures being attributed to about 15% of these malfunctions. In FY 2004 NASA will develop prototype disks and engine containment materials with inherent failure resistant characteristics that will be ready for full scale testing in FY 2005.	green		none	none	none
APG 4AT6	Controlled Flight into Terrain (CFIT) accounts for 30% of General Aviation fatal accidents. During FY 2004, NASA will complete the flight evaluation of a synthetic vision system that improves pilot situational awareness by providing a display of "out-the-window" information that is not effected by adverse metrological conditions. This system when fully implemented has the potential to eliminate 90% of CFIT accidents.	green		none	none	none
Outcome 2.1.2	By 2009, research, develop and transfer technologies that will reduce the vulnerability exposure of the aircraft, and reduce the vulnerabilities of other components in the air transportation system.	green		Outcomes originated in FY 2004		
APG 4AT7	Complete a preliminary demonstration, in a realistic operational environment, of an automated system to provide real-time identification of flight path deviations and a means to alert authorities in a prompt and consistent manner.	green		none	none	none

Goal 2
Enable a safer, more secure, efficient, and environmentally friendly air transportation system.

OBJECTIVE 2.2

Protect local and global environmental quality by reducing aircraft noise and emissions.

WHY PURSUE OBJECTIVE 2.2?

The air transportation system is integral to economic growth, national security, and enhanced quality of life. Therefore, NASA is developing technologies that reduce the negative environmental impacts of aviation operations. NASA seeks to reduce aircraft carbon dioxide greenhouse emissions by creating clean-burning engines and new energy sources like solar-electric fuel cells. The Agency's research into lighter-weight vehicles and components will reduce fuel consumption. NASA also is pursuing innovative vehicle concepts, such as blended-wing bodies and vaneless, counter-rotating turbomachinery that show potential for reducing the emissions that create smog and global warming.

Figure 75: A fan designed to reduce aircraft noise is tested in a NASA laboratory.

In addition, NASA is developing new tools that will enable researchers to identify and model aircraft noise sources and find ways to reduce this noise to acceptable, community-friendly levels. As part of this effort, NASA is exploring low-noise propulsion systems, advanced vehicle concepts, advanced materials, and innovative noise-shielding techniques that keep objectionable noise within airport boundaries. And, NASA partnerships with the aerospace industry and other government agencies are identifying the key technologies needed to increase engine and airframe efficiency and to speed the transfer of environmentally friendly technologies to the marketplace—and to local airports.

NASA'S PROGRESS AND ACHIEVEMENTS IN FY 2004

Outcome 2.2.1: By 2007, develop, demonstrate and transfer technologies that enable a reduction by half, in community noise due to aircraft, based on the 1997 state of the art.
In FY 2004, NASA validated an initial set of noise-reduction concepts for airframes and engines by testing components in wind tunnel and engine rig experiments. The concept tests verified the potential for significant noise reduction with minimal loss of performance. In addition, researchers performed acoustic (sound) and aerodynamic performance tests on a new swept and tapered wing concept in aircraft approach flow conditions. Low-noise modifications to the high-lift devices on the wings reduce noise while maintaining wing performance.

NASA also successfully tested modifications to aircraft fan and nozzle designs and validated the noise reduction predicted for those concepts. The test results validate noise-reduction projections that, when combined with benefits from other noise-reduction techniques, resulted in a five-decibel reduction relative to the 2001 state of the art. The total suite of technologies, including those developed in previous programs, is projected to reduce aircraft noise sufficiently to meet NASA's ten-year goal of reducing perceived noise from aircraft by one-half (ten decibels) relative to 1997 state of the art.

Outcome 2.2.2: By 2007, develop, demonstrate and transfer technologies for reducing NOx emission by 70% from the 1996 ICAO standard, to reduce smog and lower atmospheric ozone.

Although NASA's progress slipped by one quarter, the Agency expects to achieve this Outcome on schedule. This year, NASA produced preliminary designs for full-annular combustors (which mix fuel with air for combustion) that exhibit the low nitrous-oxide emission characteristics that were demonstrated previously in combustor sector tests. These full-annular combustor designs include considerations for commercial service, and they are compatible with existing and future engine families. They also meet requirements for flight safety, component life, affordability, and maintainability at levels appropriate for product viability. NASA plans to complete the detailed design for the 2005 full-annular combustor test by December 30, 2004.

Outcome 2.2.3: By 2007, develop, demonstrate and transfer technologies for reducing the green-house gas, CO2, emissions by 25% based on the state of the art for airframe and engine component technologies in 2000.

NASA plans to complete this Outcome in FY 2005. This year, NASA designed a two-stage compressor rig with 50 percent higher stage loading than the currently flying engine compressor. NASA also modified an existing facility to collect flow measurement data using state-of-the-art instrumentation. Researchers completed fabrication of the compressor rig hardware and began the assembly and nstrumentation process. NASA will test the two-stage compressor rig to validate its improved performance by November 30, 2004.

Figure 76: NASA's new two-stage, highly-loaded compressor casing assembly should improve engine efficiency.

Performance Measures for Objective 2.2		2004 Rating	Past Years' Performance Measures and Ratings	2003	2002	2001
Outcome 2.2.1	By 2007, develop, demonstrate and transfer technologies that enable a reduction by half, in community noise due to aircraft, based on the 1997 state of the art.	green		Outcomes originated in FY 2004		
APG 4AT8	Validate initial concepts for engine and airframe source noise reduction by 5dB (re: to CY 2001 SOA).	green		3R3 green	2R3 green	1R3 yellow
Outcome 2.2.2	By 2007, develop, demonstrate and transfer technologies for reducing NOx emission by 70% from the 1996 ICAO standard, to reduce smog and lower atmospheric ozone.	green		Outcomes originated in FY 2004		
APG 4AT19	Complete detailed design of a low-emission combustor leading to a 2005 test of a full-annular combustor demonstrating a 70% reduction of nitrogen oxides.	yellow		3R2 green	2R2 green	1R2 green
Outcome 2.2.3	By 2007, develop, demonstrate and transfer technologies for reducing the green-house gas, CO2, emissions by 25% based on the state of the art for airframe and engine component technologies in 2000.	green		Outcomes originated in FY 2004		
APG 4AT9	Experimentally demonstrate a 2-stage highly loaded compressor for increasing pressure rise per stage.	yellow		none	none	none

Note: See NASA's Performance Improvement Plan at the end of Part 2 for details on FY 2004 APGs and Outcomes rated Red, Yellow, or White.

Goal 2
Enable a safer, more secure, efficient, and environmentally friendly air transportation system.

OBJECTIVE 2.3
Enable more people and goods to travel faster and farther, with fewer delays.

WHY PURSUE OBJECTIVE 2.3?
In December 2003, the world commemorated 100 years of powered flight. Air transportation has greatly evolved over those 100 years, from fragile, propeller-driven planes to jets that allow passengers to journey across the country or across the globe with speed and ease. Since 1958, NASA technology has spurred this evolution, and the Agency continues to develop technologies for the next phase of air transportation.

Figure 77: Long queues to take off are a common problem at some airports around the country. NASA and its partners are developing technologies that will help relieve some of this congestion.

NASA is working closely with other government agencies and industry to modernize equipment, software, and procedures for significant improvements in air traffic management both in the air and on the ground. The Agency is developing and testing new vehicle concepts and technologies to reduce aircraft weight, improve aerodynamic performance, and increase speed. NASA is helping to maximize airport capacity in all types of weather, expand throughput at the Nation's small airports, effectively manage high-density traffic flows, and design aircraft that can operate on short runways. As part of this effort to improve airport flow and traffic management, NASA is developing technologies to enable high-bandwidth, highly reliable, secure networks with global connectivity, ensuring safe and secure links between aircraft and the ground. And, NASA models and simulations are helping researchers understand the human operator, improving safety and performance throughout the complex air transportation system.

NASA'S PROGRESS AND ACHIEVEMENTS IN FY 2004
Outcome 2.3.1: By 2004, develop, demonstrate and transfer technologies that enable a 35% increase in aviation system throughput in the terminal area and a 20% increase in aviation system throughput en route based on 1997 NAS capacities.

In FY 2004, NASA developed, tested, and, in some cases, transferred to the Federal Aviation Administration for deployment, advanced air transportation technologies decision support tools. These products will enable improvements in National Airspace System throughput, user flexibility, predictability, and overall system efficiency while maintaining safety. The results were so promising that the Radio Technical Commission for Aeronautics (a Federal advisory committee to the Federal Aviation Administration on policy, program, and regulatory decisions) selected NASA's Surface Management System and Multi-Center Traffic Management Advisor decision support tools to become part of the Federal Aviation Administration Free Flight Phase 2 Program, a program to create modernized computer hardware and software tools to help air traffic controllers and airlines.

Outcome 2.3.2: By 2005, develop, demonstrate and transfer key enabling capabilities for a small aircraft transportation system.

This year, NASA conducted flight experiments for Integrated Evaluation of High Volume Operations, Lower Landing Minima, and Single Pilot Performance. The results will be used to evaluate the technologies and flight scenarios for the 2005 Technology Demonstration.

Outcome 2.3.3: By 2009, develop, demonstrate, and transfer technologies that enable a further 5% increase in throughput in the terminal area and a further 10% increase in en route throughput based on 1997 NAS capacity.

NASA successfully completed two versions of the Airspace Concept Evaluation System simulation system designed to measure the effects of a new airspace concept on the National Airspace System. By modeling key features of a concept (or competing concepts), the system explores the interactions between participants and factors in the National Airspace System and decides which new concept is best. Development of the third version of the System is on schedule. The latest version features a higher fidelity terminal model, supports international flights, and has improved support for Advanced Airspace Concept modeling. In addition, NASA completed site visits to Cleveland's Air Route Traffic Control Center and Northwest Airlines' System Operations Control Center to collect field data and awarded a contract to support development of a preliminary operational concept description. Work is in progress and on schedule.

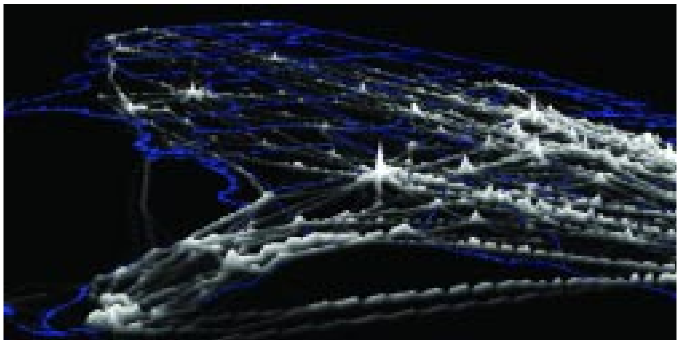


Figure 78: The Airspace Concept Evaluation System is a non-real-time modeling system for the National Airspace System. This is a JVIEW (an Air Force Research Laboratory application programmers interface) three-dimensional view of aircraft density across the United States for a 24-hour period.

Performance Measures for Objective 2.3		2004 Rating	Past Years' Performance Measures and Ratings: 2003	2002	2001
Outcome 2.3.1	By 2004, develop, demonstrate and transfer technologies that enable a 35% increase in aviation system throughput in the terminal area and a 20% increase in aviation system throughput en route based on 1997 NAS capacities.	green	Outcomes originated in FY 2004		
APG 4AT10	Complete validation and assessment of the Advanced Air Transportation Technologies products (tools/concepts) through field and laboratory demonstrations, analyses, evaluations, and assessments on a tool-by-tool basis to demonstrate an increase in terminal throughput by 35 percent and an increase in en route throughput by 20 percent.	green	3R5 green 3R4 green	2R5 green 2R4 green	none none
Outcome 2.3.2	By 2005, develop, demonstrate and transfer key enabling capabilities for a small aircraft transportation system.	green	Outcomes originated in FY 2004		
APG 4AT12	Flight demonstrate the ability to double the operations rate at non-towered, non-radar airports in low-visibility conditions using self-separation and flight-path guidance technologies for general aviation aircraft.	green	none	none	none
Outcome 2.3.3	By 2009, develop, demonstrate, and transfer technologies that enable a further 5% increase in throughput in the terminal area and a further 10% increase in en route throughput based on 1997 NAS capacity.	green	Outcomes originated in FY 2004		
APG 4AT11	Develop a non-real-time Virtual Airspace Simulation Technology environment that will model the National Airspace System and provide the capability to conduct trade-off analyses amongst concepts and technologies for the future air transportation system.	green	none	none	none
APG 4AT13	Based on research completed under AATT project and current work under VAMS project, provide preliminary analysis and assessment of distributed air/ground traffic management (DAG/TM) operational concept.	green	none	none	none

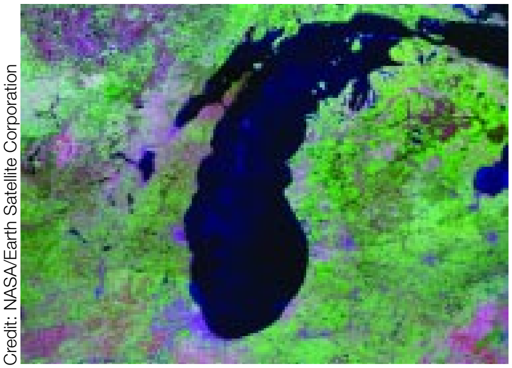
Goal 3
Create a more secure world and improve the quality of life by investing in technologies and collaborating with other agencies, industry, and academia.

OBJECTIVE 3.1

Enhance the Nation's security through partnerships with DoD, the Department of Homeland Security, and other U.S. or international government agencies.

WHY PURSUE OBJECTIVE 3.1?

NASA is a partner with the Department of Defense, the Department of Homeland Security, and other Federal agencies in maintaining national and global security. NASA maintains liaisons with these agencies, establishes joint agreements, reviews research and technology plans, and employs other mechanisms to develop common research objectives and leverage the results of each agency's research.



Credit: NASA/Earth Satellite Corporation

Figure 79: Since the beginning of 2004, NASA has supplied the U.S. Department of Agriculture (USDA) Foreign Agriculture Service with near-real-time data on lake and reservoir water heights from around the world. The USDA posts the data on the Web where anyone interested in crop production, water management, and related areas can access it. For example, the USDA has determined, using data from Jason-1 and TOPEX/Poseidon that Lake Michigan's water height has steadily declined since 1997. This image shows Lake Michigan as seen by Landsat-5 (the path of Jason-1 is depicted by series of points).

Currently, NASA is working with the Department of Defense on a number of joint projects: air-breathing hypersonic propulsion and supporting technologies, such as airframe design and materials and thermal protection systems; communications; conventional rocket-based propulsion development; remote sensing; surveillance; image processing; and advanced computing. NASA also collaborates with the National Oceanic and Atmospheric Administration, the U.S. Geological Survey, and others to ensure public safety and national security through improved climate, weather, and natural hazard forecasting, and more "accurate measurements of land cover, topography, oceans, and atmospheric properties.

NASA'S PROGRESS AND ACHIEVEMENTS IN FY 2004

Outcome 3.1.3[1]: By 2012, in partnership with the Department of Homeland Security, the Department of Defense, and the Department of State, deliver 15 observations and 5 model predictions for climate change, weather prediction and natural hazards to national and global organizations and decision-makers to evaluate 5 scenarios and optimize the use of Earth resources (food, water, energy, etc.) for homeland security, environmental security and economic security.

In FY 2004, NASA continued to collaborate with partner agencies such as the Department of Defense, Department of State, and the Department of Homeland Security to make progress in observing, modeling, and predicting natural and human-induced hazards. The Navy benchmarked use of NASA's Moderate Resolution Imaging Spectroradiometer data in their diver visibility charting tool. And, the Navy used NASA's Scatterometer and Tropical Rainfall Measuring Mission Data for their Severe Weather Forecasting Tool. NASA also worked with the Air Force to give that agency a direct link to the data streams from NASA's Terra and Aqua satellites. The Department of Homeland Security worked with NASA to evaluate the use of NASA-developed air transport and dispersion models for their Interagency Multi-Scale Atmospheric Assessment Center. NASA also provided global measurements to the Climate Change Science Program as input for scientific studies designed to address critical global change and Earth system science questions relevant to our Nation's security.

[1] Note: Due to re-organization within NASA, Outcomes 3.1.1 and 3.1.2 were discontinued with the release of the updated FY 2004 Performance Plan dated February 1, 2004.

Figure 80: The fiscal year on the International Space Station: (left) Expedition 7 Commander Yuri I. Malenchenko (left) and Flight Engineer and Science Officer Edward T. Lu, both wearing Russian Sokol suits on September 4, 2003, completed their stay on the Station in October 2003; (top right) Expedition 8 Flight Engineer Alexander Y. Kaleri (left) and Commander and Science Officer C. Michael Foale, conducting a teleconference with the Moscow Support Group for the Russian New Year celebration on December 28, 2003, were on the Station from October 2003 to April 2004; and (bottom right) Expedition 9 Flight Engineer and Science Officer Edward M. (Mike) Fincke (left) and Commander Gennady I. Padalka, posing with their Russian Orlan spacesuits in the Pirs Docking Compartment on June 10, 2004, arrived on the Station in April 2004 and were scheduled to depart in October.

Outcome 3.1.4: Demonstrate effective international collaboration on the International Space Station.

The International Space Station Partnership maintained a continuous presence of two crewmembers on-board the International Space Station throughout FY 2004. The Expedition 7 crew (Russian Commander Yuri Malenchenko and NASA Flight Engineer Ed Lu) was in residence from April to October 2003. The Expedition 8 Crew (NASA Commander Mike Foale and Russian Flight Engineer Alexander Kaleri) was in residence on-board the Station from October 2003 to April 2004. They were joined by European Space Agency Flight Engineer Pedro Duque from Spain for 1.5 weeks. Duque returned to Earth with the Expedition 7 crew. The Expedition 9 Crew (Russian Commander Gennady Padalka and NASA Flight Engineer Mike Fincke) arrived at the International Space Station in April 2004 with European Space Agency Flight Engineer André Kuipers. Kuipers, a Dutchman, returned to Earth with the Expedition 8 Crew. Throughout this period, the Station crews performed all necessary housekeeping and maintenance activities while conducting a range of scientific investigations.

Outcome 3.1.5: Transfer technology both to and from the Department of Defense.

The sole APG for this outcome (APG 4AT14) was cancelled as a result of funds redistribution due to higher priority activities, including the second flight of the X-43A. The deferral of this activity will have no impact on the primary goal of working partnerships with the Department of Defense. NASA continues to pursue and transfer dual-use technology to and from the Air Force and Army and has instituted an activity to develop dual use rotorcraft technologies. Other significant activity in this area included the successful X-43A hypersonic test flight and the July 12, 2004 initiation of checkout flights for a synthetic vision concept designed for flight at very low altitudes. NASA is developing this technology in conjunction with the Army Aviation Science and Technology

Program. It has applications to both military and civil low altitude flight operations in reduced visibility conditions. NASA also has begun working closely with the Department of Homeland Security and will have joint technology roadmaps available on schedule next year.

Performance Measures for Objective 3.1		2004 Rating	Past Years' Performance Measures and Ratings	2003	2002	2001
Outcome 3.1.3	By 2012, in partnership with the Department of Homeland Security, the Department of Defense, and the Department of State, deliver 15 observations and 5 model predictions for climate change, weather prediction and natural hazards to national and global organizations and decision-makers to evaluate 5 scenarios and optimize the use of Earth resources (food, water, energy, etc.) for homeland security, environmental security and economic security.	green		Outcomes originated in FY 2004		
APG 4ESA5	Benchmark improvements to at least two of the target national applications—air quality and agricultural competitiveness.	green		3Y29 green	2Y28 green	none
Outcome 3.1.4	Demonstrate effective international collaboration on the International Space Station.	green		Outcomes originated in FY 2004		
APG 4ISS1	In concert with the ISS International Partners, extend a continuous two-person (or greater) crew presence on the ISS through the end of FY 2004.	green		none	none	none
Outcome 3.1.5	Transfer technology both to and from the Department of Defense.	green		Outcomes originated in FY 2004		
APG 4AT14	Conduct and obtain flight test data of autonomous aerial refueling technologies in support of DoD UCAV Program.	white		none	none	none

Note: See NASA's Performance Improvement Plan at the end of Part 2 for details on FY 2004 APGs and Outcomes rated Red, Yellow, or White.

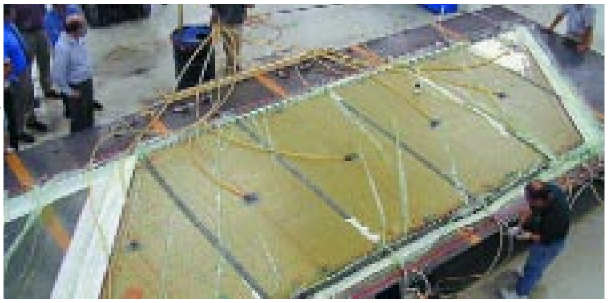
Goal 3
Create a more secure world and improve the quality of life by investing in technologies and collaborating with other agencies, industry, and academia.

OBJECTIVE 3.2

Improve the Nation's economic strength and quality of life by facilitating innovative use of NASA technology.

WHY PURSUE OBJECTIVE 3.2?

NASA research and development contributes to the Nation's well being in a number of important and sometimes unexpected ways. With its partners, NASA helps protect precious natural resources by measuring and modeling climate and weather, atmospheric properties and air quality, land coverage, and ocean and waterway health.



Credit: WebCor Technologies

Figure 81: A commercial company developed this fiber-reinforced foam technology (shown here being used to create a bridge deck panel for the U.S. Navy) with the help of NASA's Ballistic Impact Facility at Glenn Research Center. Through a technology transfer agreement, the company used the facility to make certain that their lightweight foam panels, which are being marketed for use in temporary runways, aircraft parking areas, and other structural surface uses, could withstand high-speed debris impact. In return, NASA may be able to use this strong, lightweight product for rocket fairings, cryogenic tanks, and structural members. For more information on this and other technology transfer agreements, see *Spinoff 2004*.

As a leader in aeronautics and astronautics, NASA collaborates with government and industry to provide faster, more efficient, and safer air transportation. The Agency provides unique tools, facilities, and capabilities for the study and advancement of engineering, physical sciences, biology, materials, and medicine.

NASA also works with government, industry, and academic partners to identify common research objectives and encourages these partners to invest in space research as a means to achieve mutual goals. NASA seeks to couple its technology with private-sector technology to the advantage of both by establishing joint agreements and collaborations to mature technologies and transfer them to the commercial sector where they can benefit the public.

NASA'S PROGRESS AND ACHIEVEMENTS IN FY 2004

Outcome 3.2.1: On an annual basis, develop 50 new technology transfer agreements with the Nation's industrial and entrepreneurial sectors.

In FY 2004, NASA transferred 52 technologies and facility usage agreements to private sector firms in the U.S. The transfers took place through hardware licenses, software usage agreements, or Space Act agreements. Space Act agreements allow NASA to enter into partnerships with various Federal and state agencies, private sector firms, individuals, and educational institutions to meet wide-ranging NASA mission and program requirements and objectives.

Outcome 3.2.2: By 2008, realign commercial product development to focus on NASA needs, while maintaining industrial partnerships.

In FY 2004, NASA worked with its Research Partnership Centers to focus research efforts on dual use opportunities. NASA also reorganized its space product development staff at NASA Headquarters and Marshall Space Flight Center to support and identify new NASA, other Government, and industry partnering opportunities for the Research Partnership Centers. Although NASA's space product development staff and resources helped the Research Partnership Centers in 2004, the Centers themselves must still compete for research and technology development funding. NASA conducted an internal review of the fifteen current Research Partnership Centers to evaluate each Center's potential for success in the newly competitive environment. The review was completed in April 2004, and as a result, three Centers will no longer receive funding beginning in FY 2005.

Outcome 3.2.3: By 2008, develop and test at least two design tools for advanced materials and in-space fabrication, and validate on ISS.

Because of the *Columbia* accident, there were no Shuttle flights to the International Space Station in FY 2004. Once the Shuttle resumes flight, there still will be very limited access to the International Space Station. Since in-space fabrication supports NASA's new Vision for Space Exploration, this Outcome is still viable. However, validation on the International Space Station may not be possible.

Outcome 3.2.4: By 2008, working with all OBPR research organizations and other NASA enterprises, identify at least three additional users of Research Partnership Center spaceflight hardware.

Three researchers from NASA's Exploration Systems Mission Directorate used Research Partnership Center spaceflight hardware in FY 2004. This hardware included the Commercial Generic Bioprocessing Apparatus, the Microgravity Experiment Research Locker, and the Phase Separator. Plans to increase the number of users from the Directorate are in progress.

Outcome 3.2.5: By 2008, increase by 30% (from the 2003 level) the utilization of NASA/OBPR-derived technologies by other agencies, private sector, and academia to advance basic and applied research goals of practical impact.

NASA management dropped this Outcome to support other initiatives that are focused on tasks with greater exploration relevance. As part of the efforts to re-align its resources, NASA is phasing out the following facilities that previously supported this Outcome: Multi-User Gaseous Fuels Apparatus insert for the Combustion Integration Rack; Low-Temperature Microgravity Physics Facility; Quench Module Insert for the Materials Science Research Rack; and the Biotechnology Carrier.

Performance Measures for Objective 3.2		2004 Rating	Past Years' Performance Measures and Ratings: 2003	2002	2001
Outcome 3.2.1	On an annual basis, develop 50 new technology transfer agreements with the Nation's industrial and entrepreneurial sectors.	green	Outcomes originated in FY 2004		
APG 4HRT6	Complete 50 transfers of NASA technologies, expertise or facility usage to the U.S. private sector, through hardware licenses, software usage agreements, or Space Act agreements.	green	none	none	none
Outcome 3.2.2	By 2008, realign commercial product development to focus on NASA needs, while maintaining industrial partnerships.	green	Outcomes originated in FY 2004		
APG 4RPFS1	Complete realignment plans of SPD.	green	3B9 green	2B11 green	none
APG 4RPFS2	Enable industry research in space that allows them to bring one commercial product under investigation to market by FY 2004.	green	none	none	none
Outcome 3.2.3	By 2008, develop and test at least two design tools for advanced materials and in-space fabrication, and validate on ISS.	yellow	Outcomes originated in FY 2004		
APG 4RPFS3	Complete preparations for launch of a new containerless processing facility for research on synthesis of advanced materials on ISS.	green	none	none	none
APG 4RPFS4	Continue synthesis of zeolite crystals on ISS.	yellow	none	none	none
Outcome 3.2.4	By 2008, working with all OBPR research organizations and other NASA enterprises, identify at least three additional users of Research Partnership Center spaceflight hardware.	green	Outcomes originated in FY 2004		
APG 4RPFS5	Develop a database of RPC spaceflight hardware showing potential outside users.	green	none	none	none
APG 4RPFS6	Develop a system for sharing RPC spaceflight hardware with outside users.	green	none	none	none
Outcome 3.2.5	By 2008, increase by 30% (from the 2003 level) the utilization of NASA/OBPR-derived technologies by other agencies, private sector, and academia to advance basic and applied research goals of practical impact.	white	Outcomes originated in FY 2004		
APG 4PSR1	Maintain an active research program in collaboration with other agencies in laser light scattering, bioreactor, and containerless technologies.	white	none	none	none

Note: See NASA's Performance Improvement Plan at the end of Part 2 for details on FY 2004 APGs and Outcomes rated Red, Yellow, or White.

Goal 3
Create a more secure world and improve the quality of life by investing in technologies and collaborating with other agencies, industry, and academia.

OBJECTIVE 3.3

Resolve scientific issues in the low gravity environment of space that enrich life on Earth by leading to better design tools in energy, materials, medical, and communication technologies.

WHY PURSUE OBJECTIVE 3.3?

The International Space Station is a unique facility for studying a range of scientific and engineering questions without the obscuring effects of gravity. It is the only facility where investigators can conduct hands-on, long-duration research in a true microgravity environment. NASA is working with its national and international partners to give investigators access to the Station and other space facilities and to promote the academic and commercial benefits of space-based research. Space research—enabled by research grants, commercial partnerships, and other types of agreements—contributes to a number of economically and socially important areas, including fluid, thermal, and combustion engineering science, materials research, fundamental biology, biotechnology, communications, energy production and storage, and medicine.

Figure 82: Expedition 8 Commander and Science Officer C. Michael Foale (foreground) and European Space Agency astronaut Andre Kuipers of the Netherlands work with an experiment in the Microgravity Science Glovebox in the Station's Destiny Laboratory on April 22, 2004. During the fiscal year, the Station was used to conduct research from several International Space Station partner nations.

Partnerships between NASA, industry, academia, and other government entities give to all involved access to a wider range of knowledge and capabilities. These partnerships also provide excellent opportunities to leverage the limited space flight experiment availability and a natural way for research and technology to be matured and transferred to the public.

NASA'S PROGRESS AND ACHIEVEMENTS IN FY 2004

Outcome 3.3.1: By 2008, analyze the impact of the results of the first phase of ISS and ground-based research in Biotechnology, fundamental science, and engineering to demonstrate the introduction of at least two new design tools and/or process improvements to existing technologies and industrial practices.

NASA management dropped this Outcome to support other initiatives that are focused on tasks with greater exploration relevance. As part of the efforts to re-align its resources, NASA is phasing out the following facilities that previously supported this Outcome: Multi-User Gaseous Fuels Apparatus insert for the Combustion Integration Rack; Low-Temperature Microgravity Physics Facility; Quench Module Insert for the Materials Science Research Rack; and the Biotechnology Carrier.

Outcome 3.3.2: By 2008, quantitatively assess the impact of space and ground-based research on fire safety hazard prevention and containment and on energy conversion to demonstrate measurable risk reduction and increased efficiency.

Fire safety in space, and on the ground, remains an important Agency research area. Learning more about fire leads to better ways to control fire and combustion which, in turn, saves lives, property and money. In FY 2004, NASA continued to process and analyze data retrieved from Space Shuttle *Columbia* on fire safety and microgravity combustion.

Outcome 3.3.3: By 2008, develop at least three new leveraged research partnerships with industry, academia, and other government agencies that improve NASA spacecraft safety.

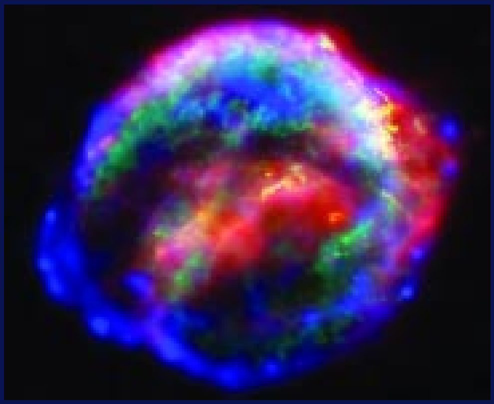
NASA currently is solidifying several partnerships in research applicable to spacecraft safety and is developing several technologies and tools for safer spacecraft. These include: a fire suppression device for new spacecraft (e.g., the Crew Exploration Vehicle) and for planetary habitats (e.g., research bases on the Moon and Mars); a lightweight, pointable, hyperspectral sensor to detect environmental contaminants (e.g., toxins, leaks); an integrated surveillance system for physiological sensing on astronauts, (e.g., heart rate, basal metabolic rate); and a prototype monitoring and communication system for integration into astronauts' Extra Vehicular Activity space suits.

Performance Measures for Objective 3.3		2004 Rating	Past Years' Performance Measures and Ratings	2003	2002	2001
Outcome 3.3.1	By 2008, analyze the impact of the results of the first phase of ISS and ground-based research in biotechnology, fundamental science, and engineering to demonstrate the introduction of at least two new design tools and/or process improvements to existing technologies and industrial practices.	white		Outcomes originated in FY 2004		
APG 4PSR2	Demonstrate the productivity of the research program in combustion, fluids physics, biotechnology, and materials science and accomplish the milestones of ISS research projects.	white		none	none	none
Outcome 3.3.2	By 2008, quantitatively assess the impact of space and ground-based research on fire safety hazard prevention and containment and on energy conversion to demonstrate measurable risk reduction and increased efficiency.	green		Outcomes originated in FY 2004		
APG 4PSR3	Process and analyze existing STS-107 data on fire safety and microgravity combustion research and maintain a productive ground and flight-based research program.	green		3B6 yellow	2B8 green	none
Outcome 3.3.3	By 2008, develop at least three new leveraged research partnerships with industry, academia, and other government agencies that improve NASA spacecraft safety.	green		Outcomes originated in FY 2004		
APG 4RPFS7	Develop at least one enabling technology to improve the safety of space transportation systems.	green		none	none	none

Note: See NASA's Performance Improvement Plan at the end of Part 2 for details on FY 2004 APGs and Outcomes rated Red, Yellow, or White.

Mission: To Explore the Universe and Search for Life

Goal 4: Explore the fundamental principles of physics, chemistry, and biology through research in the unique natural laboratory of space.



Goal 5: Explore the solar system and the universe beyond, understand the origin and evolution of life, and search for evidence of life elsewhere.

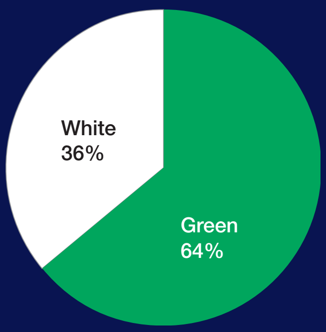
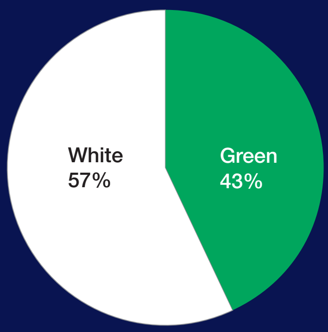


Figure 83: NASA achieved 64 percent of the APGs in Goal 4.



NASA is on track to achieve 43 percent of its Outcomes under Goal 4.

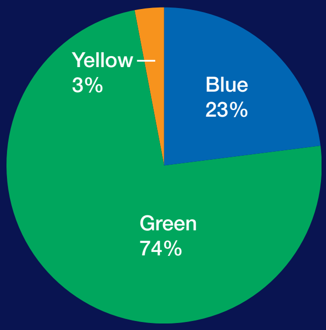
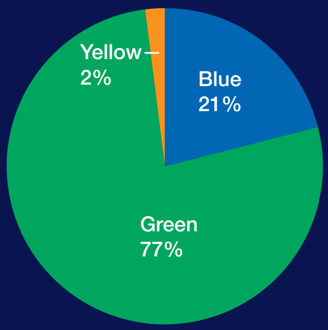


Figure 84: NASA achieved 97 percent of the APGs in Goal 5.



NASA is on track to achieve 98 percent of its Outcomes under Goal 5.

APG color ratings:

- Blue: Significantly exceeded APG
- Green: Achieved APG
- Yellow: Failed to achieve APG, progress was significant, and achievement is anticipated within the next fiscal year.
- Red: Failed to achieve APG, do not anticipate completion within the next fiscal year.
- White: APG was postponed or cancelled by management directive.

Outcome color ratings:

- Blue: Significantly exceeded all APGs. On track to exceed this Outcome as stated.
- Green: Achieved most APGs. On track to fully achieve this Outcome as stated.
- Yellow: Progress toward this Outcome was significant. However, this Outcome may not be achieved as stated.
- Red: Failed to achieve most APGs. Do not expect to achieve this Outcome as stated.
- White: This outcome as stated was postponed or cancelled by management directive or the Outcome is no longer applicable as stated based on management changes to the APGs.

Goal 4
Explore the fundamental principles of physics, chemistry, and biology through research in the unique natural laboratory of space.

OBJECTIVE 4.1

Determine how fundamental biological processes of life respond to gravity and space environments.

WHY PURSUE OBJECTIVE 4.1?

Life on Earth evolved in response to Earth's gravity and protective environment. But what happens to living systems when they are transported to space? This question is key as humans seek to venture past the protection of Earth to explore the Moon, Mars, and beyond.

Figure 85: NASA uses this tiny worm, *C. elegans*, to study how organisms respond to gravity at the molecular, cellular, developmental, and behavioral levels. *C. elegans* last flew aboard the International Space Station during Expedition 9 in 2004 as part of the International Caenorhabditis Elegans first international biology experiment (ICE-First), a collaborative research project involving the United States, France, Japan, and Canada.

NASA is conducting fundamental biological research on how terrestrial life (e.g., cells, bacteria, insects, plants, animals) form, organize, grow, and function in space. NASA seeks answers to questions about changes at the physical, chemical, molecular, and cellular level—changes affecting the whole organism. NASA also is studying the complex interaction of multiple species in closed environments and exploring answers to the following critical questions:

- Does space affect life at its most fundamental levels, from the gene to the cell?
- How does long-term exposure to space affect organisms?
- How does space affect the life cycles of organisms from one to many generations?
- How do systems of organisms change in space?

While this research will provide critical strategic information for human exploration, it also will provide new information on life in general.

NASA'S PROGRESS AND ACHIEVEMENTS IN FY 2004

Outcome 4.1.1: Use ground-based simulators and ISS to determine gravity responses for at least five model organisms by 2008.

NASA solicited a number of research proposals from the science community to conduct ground-based studies on model organisms. The research to be conducted will focus on both plant and microbial organisms. NASA also participated in the "International Plant Workshop" which established a research roadmap and goals, and the "Animal Research in Support of Human Space Exploration" workshop, which resulted in recommendations of optimal model organisms for different biomedical problems. NASA also continued its active, ongoing hypergravity research program at Ames Research Center's Center for Gravitational Biology Research.

Outcome 4.1.2: Develop predictive models of cellular, pathogenic, and ecological responses to space for at least two organisms by 2008.

NASA continued to make satisfactory progress towards its 2008 goal for this Outcome by soliciting a number of research proposals from the science community to research and develop predictive models for model organisms. The research will focus on both plant and microbial organisms. In FY 2004, NASA researchers also participated in, and/or organized, a number of workshops, including: "Animal Research in Support of Human Space Exploration," "Office of Biological and Physical Research Microbial Models," "What do you need to know about Cell Biology Experiments in Space," and the "NASA Cell Science Conference Annual Investigator Workshop."

Outcome 4.1.3: By 2008, structure the Fundamental Space Biology flight research program to emphasize at least five model organisms and teams of Principal Investigators. Working towards NASA's 2008 goal for this Outcome, the Agency solicited a number of research proposals from the science community to research four model organisms. NASA and the International Space Life Sciences Working Group will form research teams prioritized according to Critical Path Roadmap Risks and NASA's Vision for Space Exploration. NASA also completed a re-evaluation of International Space Station and Shuttle flight hardware and habitats with respect to research goals and resources. In the area of cell science, research will focus on hardware that is already on-orbit or which will be completed this fiscal year (e.g., commercial incubator and cellular biotechnology incubator, Single Loop Cell Culture). These experiments have not yet been manifested for flight, but they are planned to begin in FY 2005. In the area of animal research, NASA will continue to use Animal Enclosure Modules on the Shuttle's middeck. This hardware has supported rodent research since the late 1980s. NASA also is identifying the critical questions and risks that should have the highest priority for study on the International Space Station when the Advanced Animal Habitat and Centrifuge become available. In the area of plant research, NASA has focused International Space Station plant research on the European Modular Cultivation System, which has a variable gravity centrifuge that will be used to simulate lunar and Martian gravity. The first of these experiments will be conducted no earlier than International Space Station Increment 11, following the second return to flight mission in July 2005.

Performance Measures for Objective 4.1		2004 Rating	Past Years' Performance Measures and Ratings	2003	2002	2001
Outcome 4.1.1	Use ground-based simulators and ISS to determine gravity responses for at least five model organisms by 2008.	green		Outcomes originated in FY 2004		
APG 4BSR1	Solicit ground-based research on two widely studied model organisms.	green		none	none	none
APG 4BSR2	Produce a road map and strategic goals for plant research ground-based studies and flight opportunities. Solicit flight-based research on at least one model plant species.	green		none	none	none
Outcome 4.1.2	Develop predictive models of cellular, pathogenic, and ecological responses to space for at least two organisms by 2008.	green		Outcomes originated in FY 2004		
APG 4BSR3	Solicit ground-based research on responses of cells and pathogens to space environments.	green		none	none	none
APG 4BSR4	Select two model species to support the development of predictive models. Communicate with the research community in workshops and at national and international scientific meetings about the approach.	green		none	none	none
Outcome 4.1.3	By 2008, structure the Fundamental Space Biology flight research program to emphasize at least five model organisms and teams of Principal Investigators.	green		Outcomes originated in FY 2004		
APG 4BSR5	In coordination with International partners, solicit flight research on two model organisms and establish at least two research teams.	green		none	none	none
APG 4BSR6	Review and reprioritize Fundamental Space Biology flight experiments with a focus on model specimens.	green		none	none	none
APG 4BSR7	Reevaluate flight hardware and habitats with respect to research goals and focus resources on select units.	green		none	none	none

Goal 4
Explore the fundamental principles of physics, chemistry, and biology through research in the unique natural laboratory of space.

OBJECTIVE 4.2

Expand understanding of fundamental physical processes and insight into the laws of nature through space-based investigation.

WHY PURSUE OBJECTIVE 4.2?

Gravity affects everything humans do on Earth. It molds living things and influences the physical processes occurring around the globe. But gravity also blinds humans to a realm of other, more subtle forces that drive the physical world. NASA is using its unique resources to study these "secondary" forces. By studying the physical forces that regulate the behavior of fluids, gases, and solids, researchers gain new insights into the areas of materials processing, propulsion, energy production and storage, chemistry, biotechnology, biology, communications, combustion, and others. NASA researchers also are gaining a better understanding of nature's complexity and how order arises from seemingly chaotic interactions. The synergy and vigor achieved through NASA's interdisciplinary research into fundamental physical processes helps the Agency meet its exploration goals and ensures that NASA's contribution to fundamental research is at the leading edge of science.

Figure 86: Expedition 9 Science Officer Mike Fincke works with equipment for the Binary Colloidal Alloy Test-3 experiment in the Station's Destiny Laboratory on April 27, 2004. The experiment studied the long-term behavior of colloids—a system of fine particles suspended in a fluid like paint or milk—in a low gravity environment.

NASA'S PROGRESS AND ACHIEVEMENTS IN FY 2004

In FY 2004, NASA management dropped the four Outcomes under this Objective to support other initiatives that are focused on tasks with greater exploration relevance. As part of the Agency's effort to realign resources, NASA terminated the Low-Temperature Microgravity Physics Facility that supported Outcomes 4.2.1, 4.2.2, and 4.2.3. Because of the realignment of the Biotechnology program, NASA also terminated the International Space Station Biotechnology facility that previously supported Outcome 4.2.4.

Objective 4.2 was continued in NASA's FY 2005 Integrated Budget and Performance Document (Performance Plan). These Outcomes will be reconsidered based on resource availability and Agency priorities in FY 2005 and beyond.

Outcome 4.2.1: By 2008, complete the first generation of ISS research in colloidal physics and soft condensed matter and demonstrate the ability to control the colloidal engineering of at least two different model structures.
Deferred until FY 2005.

Outcome 4.2.2: By 2008, complete the design and fabrication of the first ISS fundamental microgravity physics facility to allow the performance of two capstone investigations in dynamical critical phenomena.
Deferred until FY 2005.

Outcome 4.2.3: By 2008, complete the design for the ISS laser-cooling laboratory and demonstrate the feasibility to deploy the most accurate atomic clock in space.
Deferred until FY 2005.

Outcome 4.2.4: By 2008, complete the first phase of the ISS biotechnology facility and demonstrate cellular biotechnology research throughput increase by a factor of two.
Deferred until FY 2005.

Performance Measures for Objective 4.2		2004 Rating	Past Years' Performance Measures and Ratings	2003	2002	2001
Outcome 4.2.1	By 2008, complete the first generation of ISS research in colloidal physics and soft condensed matter and demonstrate the ability to control the colloidal engineering of at least two different model structures.	white		Outcomes originated in FY 2004		
APG 4PSR4	Demonstrate the productivity of the colloidal physics and soft-condensed matter program and accomplish the planned ISS research projects milestones.	white		none	none	none
Outcome 4.2.2	By 2008, complete the design and fabrication of the first ISS fundamental microgravity physics facility to allow the performance of two capstone investigations in dynamical critical phenomena.	white		Outcomes originated in FY 2004		
APG 4PSR5	Demonstrate the accomplishments of the ISS fundamental physics facility development milestones and maintain a productive ground and space-based research program in condensed matter physics.	white		none	none	none
Outcome 4.2.3	By 2008, complete the design for the ISS laser-cooling laboratory and demonstrate the feasibility to deploy the most accurate atomic clock in space.	white		Outcomes originated in FY 2004		
APG 4PSR6	Demonstrate the accomplishments of the ISS laser cooling and atomic physics facility milestones and maintain an innovative and productive ground and space-based research program in atomic and gravitational physics.	white		3B5 green	2B7 green	none
Outcome 4.2.4	By 2008, complete the first phase of the ISS biotechnology facility and demonstrate cellular biotechnology research throughput increase by a factor of two.	white		Outcomes originated in FY 2004		
APG 4PSR7	Demonstrate the accomplishments of the ISS biotechnology research facility development milestones and maintain a productive and innovative ground and space-based research program in cellular biotechnology and tissue engineering.	white		none	none	none

Note: See NASA's Performance Improvement Plan at the end of Part 2 for details on FY 2004 APGs and Outcomes rated Red, Yellow, or White.

Goal 5
Explore the solar system and the universe beyond, understand the origin and evolution of life, and search for evidence of life elsewhere.

OBJECTIVE 5.1

Learn how the solar system originated and evolved to its current diverse state.

WHY PURSUE OBJECTIVE 5.1?

Earth's solar system is a place of beauty, and continuous change. The Sun's planets have numerous moons with diverse characteristics, and each tells a story about the evolution of the solar system. Within the first billion years of the solar system's five-billion-year history, the planets formed and life began to emerge on Earth and, perhaps, elsewhere. Many of the current characteristics of the solar system were determined during this critical formative epoch.

Credit: NASA JPL/Caltech

Figure 87: The Stardust spacecraft, shown here in an artist's rendition, successfully flew through the coma of comet Wild 2 in January 2004. During its rendezvous, it captured interstellar dust samples and stored them in aerogel, a silica-based material, for their trip back to Earth. Comets, which scientists believe are the oldest, most primitive objects in the solar system, may have left the first water on Earth.

The planets, moons, and ancient icy bodies that reside far from the Sun are thought to be a repository of relatively pristine materials from this time, and therefore, hold keys that can help unlock the mysteries of the solar system's origins. NASA is gaining a better understanding of the evolution of the solar system through outer solar system exploration and through the surface exploration and return of samples from the inner planets and small bodies. NASA's exploration of this solar system also will provide insight into the formation of other solar systems.

NASA'S PROGRESS AND ACHIEVEMENTS IN FY 2004

The Space Science Advisory Committee, an external advisory board, reviewed the progress of Outcomes 5.1.1 through 5.1.4 and determined that NASA successfully demonstrated progress in all four Outcomes during FY 2004.

Outcome 5.1.1: Understand the initial stages of planet and satellite formation.

A number of NASA's initiatives contributed to the Agency's progress, including the Stardust mission, the Genesis mission, and NASA's Planetary Astronomy program.

- NASA's Stardust mission successfully flew through the coma of comet Wild 2 on January 2, 2004 and collected approximately three times the amount of cometary dust expected. Cometary dust is the mineral portion of the material that formed the outer planets (Jupiter, Saturn, Uranus, and Neptune). Stardust will return its sample of comet dust to Earth in January 2006 for detailed laboratory analysis.

- NASA's Genesis spacecraft successfully completed its 22-month phase of collecting solar wind particles in April 2004. Scientists theorize that solar wind particles might accurately preserve the original mix of elements (atoms) that formed the Sun and planets. Genesis returned its samples to Earth in September 2004. Although the soft landing was unsuccessful, researchers are optimistic that the bulk of the samples will be viable for detailed laboratory analysis.
- Researchers funded by NASA's Planetary Astronomy program discovered the most distant object found to date in the solar system. Tentatively named "Sedna," this object, between 800 and 1100 miles in diameter, is somewhat smaller than Pluto. It orbits the Sun in a highly eccentric path that approaches within 8 billion miles of the Sun (over twice Pluto's average distance) at its closest, but recedes to 84 billion miles at its farthest during its 10,500-year orbital period.

Outcome 5.1.2: Understand the processes that determine the characteristics of bodies in our solar system and how these processes operate and interact.

Two major activities contributed to NASA's progress in this Outcome: NASA's Cassini mission; and the proposed Jupiter Icy Moons Orbiter mission. First, NASA's Cassini spacecraft successfully entered Saturn's orbit and returned images of Saturn's rings that revealed waves of various types, scalloped ring edges, and braiding not seen by previous planetary spacecraft. These highly detailed images greatly enhanced researchers' ability to understand the nature and evolution of ring systems. Second, the Jupiter Icy Moons Orbiter Science Definition Team formulated four primary goals for its mission, including objectives and measurements. Initial studies for the Jupiter Icy Moons Orbiter mission are underway. The mission will use nuclear electric power and propulsion to enable comprehensive exploration of Jupiter's icy moons (Europa, Ganymede, and Callisto), to acquire extensive observations of Jupiter, Io, and other bodies, and to investigate the dynamics and processes at work in Jupiter's system.

Outcome 5.1.3: Understand why the terrestrial planets are so different from one another.

The launch of the MESSENGER mission and improvements in planetary simulations contributed to NASA's progress in this Outcome. NASA's MESSENGER mission to Mercury launched successfully on August 3, 2004. MESSENGER will conduct a comprehensive geological, geophysical, and geochemical survey of the planet Mercury. NASA researchers also used novel numerical techniques to show diversity in terrestrial planet sizes, positions, and sources of water to simulate this and other solar systems.

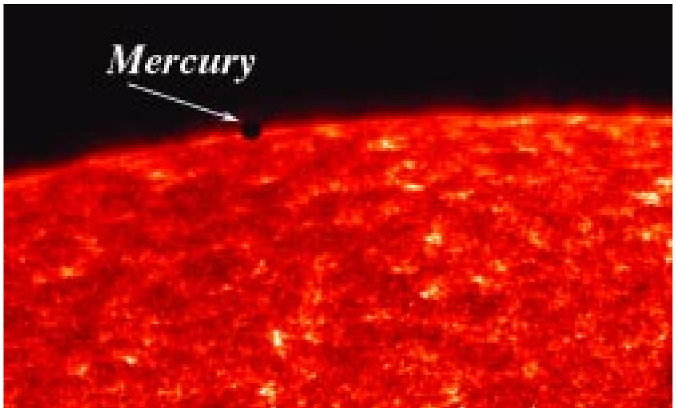


Figure 88: The MESSENGER spacecraft will visit Mercury, the innermost planet of this solar system, shown here in an image (taken by the TRACE satellite in Earth orbit) of the terrestrial planet during solar transit on November 15, 1999.

Preliminary results indicate that the amount of gas present when planets form determines whether Earth-sized or Mars-sized planets form. These simulations provide predictions that can be tested with future Mars and Venus missions, as well as missions designed to search for planets around other stars.

Outcome 5.1.4: Learn what our solar system can tell us about extra-solar planetary systems.

NASA researchers revealed that Jupiter and Saturn's positions relative to each other might reflect dynamic processes common to planetary systems. Theoretical studies, together with the existence of at least one extra-solar planetary system, suggest that the 5:2 ratio of the orbit periods of Jupiter and Saturn might be a common relationship between two giant planets. This also implies that giant planets migrating inward during solar system formation might naturally end up in special orbital relationships like that of Jupiter and Saturn.

Performance Measures for Objective 5.1		2004 Rating	Past Years' Performance Measures and Ratings	2003	2002	2001
Outcome 5.1.1	Understand the initial stages of planet and satellite formation.	yellow		Outcomes originated in FY 2004		
APG 4SSE12	Successfully demonstrate progress in understanding the initial stages of planet and satellite formation. Progress towards achieving outcomes will be validated by external review.	yellow		none	none	none
Outcome 5.1.2	Understand the processes that determine the characteristics of bodies in our solar system and how these processes operate and interact.	green		Outcomes originated in FY 2004		
APG 4SSE13	Successfully demonstrate progress in studying the processes that determine the characteristics of bodies in our solar system and how these processes operate and interact. Progress towards achieving outcomes will be validated by external review.	green		3S3 green	2S3 green	none
Outcome 5.1.3	Understand why the terrestrial planets are so different from one another.	green		Outcomes originated in FY 2004		
APG 4SSE14	Successfully demonstrate progress in understanding why the terrestrial planets are so different from one another. Progress towards achieving outcomes will be validated by external review.	green		3S5 green	2S5 green	1S10 blue
Outcome 5.1.4	Learn what our solar system can tell us about extra-solar planetary systems.	green		Outcomes originated in FY 2004		
APG 4SSE15	Successfully demonstrate progress in learning what our solar system can tell us about extra-solar planetary systems. Progress towards achieving outcomes will be validated by external review.	green		none	none	none

Note: See NASA's Performance Improvement Plan at the end of Part 2 for details on FY 2004 APGs and Outcomes rated Red, Yellow, or White.

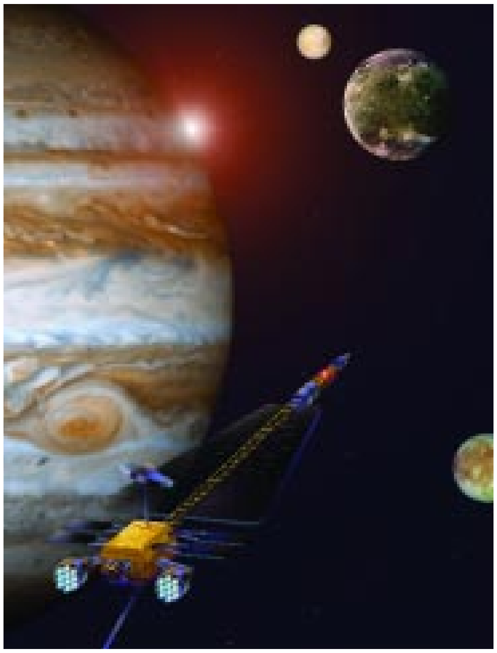
Goal 5
Explore the solar system and the universe beyond, understand the origin and evolution of life, and search for evidence of life elsewhere.

OBJECTIVE 5.2

Understand how life begins and evolves and determine the characteristics of the solar system that led to the origin of life.

WHY PURSUE OBJECTIVE 5.2?

The essential requirements for life on Earth are organic material, liquid water, and a source of usable energy. The availability of all these ingredients defines whether or not a planet is "habitable." The "habitable zone" of a solar system is defined as the region harboring habitable planets. Scientists once thought that the habitable zone of the solar system was limited, primarily by a need for the right amount of sunlight, to a fairly narrow region around Earth's distance from the Sun. The discovery that great tides on Europa, an icy moon of Jupiter, heat the planet's interior and create a liquid ocean under its ice-bound surface, and the discovery on Earth of microbial life-forms that survive and thrive at extremely high and low temperatures and in extreme acidity, salinity, alkalinity, and concentrations of heavy metals that were once considered lethal, have expanded scientists' views regarding the range of conditions capable of supporting life and what constitutes habitable zones in this solar system and beyond.



Credit: NASA JPL/Caltech

Figure 88: The Jupiter Icy Moons Orbiter, shown here in an artist's concept, will visit Callisto, Ganymede, and Europa, each of which have the three ingredients considered essential for life: water, energy, and the necessary chemical contents. The mission will investigate the moons to find out more about their makeup, history, and potential for sustaining life.

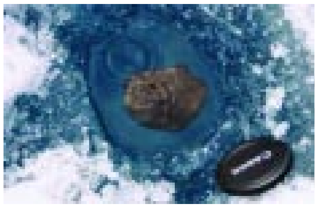
NASA is studying Earth's geological and biological records to determine the historical relationship between Earth and its living organisms. From this, NASA is seeking to determine the sources of organic compounds that could lead to life and to understand their roles in the processes that take place on any newly formed planet. NASA also is planning and conducting missions to planetary bodies in the solar system, including Mars and three moons of Jupiter, that may harbor some of the key components necessary for life.

NASA'S PROGRESS AND ACHIEVEMENTS IN FY 2004

The Space Science Advisory Committee, an external advisory board, reviewed the progress of Outcomes 5.2.1 through 5.2.4 and determined that NASA successfully demonstrated progress in all four Outcomes during FY 2004.

Outcome 5.2.1: Determine the nature, history, and distribution of volatile and organic compounds in the solar system.

Recent research indicates miniscule interplanetary dust particles and meteorites collected from Earth's stratosphere by NASA aircraft since the mid-1970s contain significant concentrations of simple hydrocarbons and have not been altered much by contact with water. This indicates that pre-biotic organic matter was abundant in the early solar system and formed prior to the incorporation of interplanetary dust particles into asteroids and comets. Researchers studying the



Credit: University of Calgary/University of Western Ontario

Figure 89: The Tagish Lake meteorite, shown here next to a camera lens cap for scale, contains the oldest organic materials—tiny bits of interstellar dust—ever found. Its materials provide clues to the solar system's formation approximately 4.6 billion years ago. The meteorite plummeted to Earth and landed on a frozen lake in British Columbia, Canada, in January 2000.

Tagish Lake meteorite, which fell in Canada in January 2000, identified microscopic globules of organic material with compositions that indicate they formed from pre-solar materials. These are the oldest organic compounds yet discovered. Further study of these globules should provide important clues about chemical reactions in the cold molecular clouds from which stars form and the processes present in the early solar system. The NASA Cosmochemistry Program partly funded these international studies.

Outcome 5.2.2: Identify the habitable zones in the solar system.
Activities contributing to NASA's progress included discoveries by the twin Mars rovers (*Spirit* and *Opportunity*) and experiments in Chile's Atacama Desert. *Opportunity* found evidence that portions of Mars may have had habitable environments in the past. At its landing site within a small crater in Meridiani Planum, *Opportunity* discovered unambiguous evidence that ponds (and perhaps larger bodies) of salty water stood at that location long enough to produce sedimentary rocks. It found this evidence in the uppermost (and therefore, geologically, the most recent) sediment layers. Meanwhile, in Chile's Atacama Desert, experiments patterned after the Viking biology experiment, and funded by the NASA Astrobiology program, showed active non-biological decomposition of organic chemicals in those soils. Researchers conducted these studies in the Atacama Desert because some areas of the desert are so dry that no indigenous life is found; its dry soils lack organics and show the presence of one or more reactive oxidants. Studies like this help researchers understand analyses of other planets.

Outcome 5.2.3: Identify the sources of simple chemicals that contribute to pre-biotic evolution and the emergence of life.
NASA made significant progress in understanding the basic sugars present in the molecules that make up RNA and DNA, the molecules that carry the genetic codes for all life on Earth. Ribose is a type of sugar that forms the "backbone" of RNA and DNA. The formation of ribose appears to be a natural outcome of chemical transformation of non-biological organic molecules that were present in the earliest stages of the solar system's formation. Ribose is chemically unstable in liquid water. However, recent studies funded by the NASA Astrobiology program revealed that borate minerals (like the common household cleaner borax) stabilize ribose in water. Consequently, ribose could have formed by non-biological chemical processes in water before life emerged on Earth, a finding that would overcome a longstanding hurdle in understanding the emergence of life on Earth.

Outcome 5.2.4: Study Earth's geologic and biologic records to determine the historical relationship between Earth and its biosphere.
Two hundred fifty million years ago, the Permian geological era ended with the greatest mass extinction in Earth's history: more than 90 percent of marine species and more than 70 percent of terrestrial species perished. Suggestions that it was caused by a massive impact of an asteroid or comet gained support recently when researchers identified a geological structure named Bedout, offshore of northwestern Australia, as a potential impact crater. Research funded jointly by the National Science Foundation and the NASA Astrobiology program identified evidence of impact in cores taken from the Bedout structure. In other research, scientists revealed that identifying the nature of the last universal common ancestor of life might be impossible. The patterns of coalescence of genetic sequence data indicates that different genes trace back to ancestors of different ages, so, there may have been no single last common ancestor of all genetic sequences. Distinguishing between asteroid impacts and massive volcanic activity as the cause of large extinctions on Earth is difficult because of the possibility that large impacts cause large-scale volcanic events. A NASA-funded theoretical study using detailed computer modeling of impacts and their effects on the Earth's crust determined that impacts must be so large in order to trigger large-scale volcanic flows that the two mechanisms for global extinction must be considered as separate possible causes rather than as coupled causes.

Performance Measures for Objective 5.2		2004 Rating	Past Years' Performance Measures and Ratings	2003	2002	2001
Outcome 5.2.1	Determine the nature, history, and distribution of volatile and organic compounds in the solar system.	green		Outcomes originated in FY 2004		
APG 4SSE16	Successfully demonstrate progress in determining the nature, history, and distribution of volatile and organic compounds in the solar system. Progress towards achieving outcomes will be validated by external review.	green		none	none	none
Outcome 5.2.2	Identify the habitable zones in the solar system.	green		Outcomes originated in FY 2004		
APG 4SSE17	Successfully demonstrate progress in identifying the habitable zones in the solar system. Progress towards achieving outcomes will be validated by external review.	green		3S6 green	2S6 green	none
Outcome 5.2.3	Identify the sources of simple chemicals that contribute to pre-biotic evolution and the emergence of life.	green		Outcomes originated in FY 2004		
APG 4SSE18	Successfully demonstrate progress in identifying the sources of simple chemicals that contribute to prebiotic evolution and the emergence of life. Progress towards achieving outcomes will be validated by external review.	green		3S6 green	2S6 green	none
Outcome 5.2.4	Study Earth's geologic and biologic records to determine the historical relationship between Earth and its biosphere.	green		Outcomes originated in FY 2004		
APG 4SSE19	Successfully demonstrate progress in studying Earth's geologic and biologic records to determine the historical relationship between Earth and its biosphere. Progress towards achieving outcomes will be validated by external review.	green		none	none	none

Goal 5
Explore the solar system and the universe beyond, understand the origin and evolution of life, and search for evidence of life elsewhere.

OBJECTIVE 5.3

Understand the current state and evolution of the atmosphere, surface, and interior of Mars.

WHY PURSUE OBJECTIVE 5.3?

Mars holds a special place in the solar system by virtue of its similarities to Earth, its potential f or having been a home for life, and its value as a "natural laboratory" for understanding the environmental and geological evolution of the rocky planets of the inner solar system. Mars' atmosphere, surface, and interior, and their interactions with one another, can tell researchers much about the environment in which life could have developed and thrived. By characterizing these interactions, researchers also gain insight into the conditions that could spawn and support life elsewhere in the universe.

Credit: NASA JPL/Cornell

Figure 90: The Mars rover *Opportunity* took this picture of a rock called "Berry Bowl" in the Eagle Crater outcrop in March 2004. The surrounding area is strewn with sphere-like granules, called "blueberries," that contain hematite that was deposited in the rock by water that once flowed on Mars.

NASA'S PROGRESS AND ACHIEVEMENTS IN FY 2004

The Space Science Advisory Committee, an external advisory board, reviewed the progress of Outcomes 5.3.1 through 5.3.4 and determined that NASA successfully demonstrated progress in all four Outcomes during FY 2004. In two of the Outcomes (5.3.2 and 5.3.3), the Space Science Advisory Committee recommended a "blue" rating indicating exceptional achievement (e.g., results of major importance or significant unexpected discoveries), relative to resources invested in those research focus areas.

Outcome 5.3.1: Characterize the present climate of Mars and determine how it has evolved over time.

NASA researchers gained a new view of the climate history of Mars thanks to more than two Mars years (one Mars year is equal to 687 Earth days) of observations from Mars Global Surveyor and new boundary conditions provided by Mars Odyssey. This new synthesis of data emphasizes the possibility of an active water cycle resulting in snow and ice on the surface during the most recent climate cycles on the planet.

Outcome 5.3.2: Understand the history and behavior of water and other volatiles on Mars.

The successful mission of the Mars Exploration Rovers, *Spirit* and *Opportunity*, that landed on Mars, completed their 90-day prime missions successfully, and continue to explore the Martian surface, contributed to NASA's exceptional progress in this Outcome. *Spirit* found evidence that small amounts of water had been present in cracks in the rocks and in the soil on the floor of Gusev crater. *Opportunity* found evidence that standing pools of water once existed in Meridiani Planum. *Spirit* is currently examining a low range of hills that are revealing additional clues to past conditions in Gusev crater. The Mars Global Surveyor also uncovered the first evidence of a former river delta on Mars. This fan-shaped apron of debris indicates persistent flow of water over a period that lasted from thousands to millions of years.

Credit: NASA JPL/Malin Space Science Systems

Figure 91: In November 2003, the Mars Global Surveyor took several images that shows where a meandering stream was cut-off as the channel adjusted its course. The image series, taken of a crater at 24.3°S, 33.5°W, shows the first evidence of an ancient river delta on Mars.

Outcome 5.3.3: Understand the chemistry, mineralogy, and chronology of Martian materials.

Quantitative assessments of dozens of Martian soil samples and rocks produced by the Mars Exploration Rovers *Spirit* and *Opportunity* contributed to NASA's exceptional progress in this Outcome. NASA was able to link the analyses of the chemical and mineral compositions of the various soils and rocks in two distinctly different locations on Mars to orbital remote sensing data from Mars Odyssey and Mars Global Surveyor. An analysis of crater images in Meridiani Planum showed that these deposits were at the top of a 300-meter thick sequence of layers that overlies Noachian (the earliest geological era on Mars) cratered terrain. Further analysis produced strong evidence for significant erosion, probably by wind-driven processes, much later in time. Mars Odyssey also completed a global mapping of Mars elements with its Gamma Ray Spectrometer suite, providing an assessment of the bulk chemical composition of the Martian crust at regional scales.

Outcome 5.3.4: Determine the characteristics and dynamics of the interior of Mars.

Studies of Martian meteorites funded by NASA's Cosmochemistry program revealed distinctive mineral reservoirs in the Martian mantle (the layer below Mars' surface or "crust") that were established when the mantle solidified 4.5 billion years ago. This meteorite work provides a fundamental framework for interpreting global data obtained by remote sensing satellites in Mars orbit.

Performance Measures for Objective 5.3		2004 Rating	Past Years' Performance Measures and Ratings	2003	2002	2001
Outcome 5.3.1	Characterize the present climate of Mars and determine how it has evolved over time.	green		Outcomes originated in FY 2004		
APG 4MEP9	Successfully demonstrate progress in characterizing the present climate of Mars and determine how it has evolved over time. Progress towards achieving outcomes will be validated by external review.	green		none	none	none
Outcome 5.3.2	Understand the history and behavior of water and other volatiles on Mars.	blue		Outcomes originated in FY 2004		
APG 4MEP10	Successfully demonstrate progress in investigating the history and behavior of water and other volatiles on Mars. Progress towards achieving outcomes will be validated by external review.	blue		none	none	none
Outcome 5.3.3	Understand the chemistry, mineralogy, and chronology of Martian materials.	blue		Outcomes originated in FY 2004		
APG 4MEP11	Successfully demonstrate progress in studying the chemistry, mineralogy, and chronology of Martian materials. Progress towards achieving outcomes will be validated by external review.	blue		none	none	none
Outcome 5.3.4	Determine the characteristics and dynamics of the interior of Mars.	green		Outcomes originated in FY 2004		
APG 4MEP12	Successfully demonstrate progress in determining the characteristics and dynamics of the interior of Mars. Progress towards achieving outcomes will be validated by external review.	green		none	none	none

Goal 5
Explore the solar system and the universe beyond, understand the origin and evolution of life, and search for evidence of life elsewhere.

OBJECTIVE 5.4

Determine if life exists or has ever existed on Mars.

WHY PURSUE OBJECTIVE 5.4?

In 1877, Italian astronomer Giovanni Virginio Schiaparelli announced that he had observed "canali," linear markings, on the surface of Mars. Although "canali" means "channels" in Italian, poor translations led some to believe that Martian inhabitants had built canals across the surface of Mars. Since then, the concept of life on Mars has been a popular theme in literature, films, and television. But, is the concept more than science fiction? The discovery of life, past or present, on Mars would be a defining moment for humankind.

Credit: NASA JPL/Cornell

Figure 92: The rover *Spirit* used its abrasion tool to take samples of a relatively soft rock called "Wooly Patch" near the base of "Columbia Hills" inside the Gusev Crater on July 30, 2004. Scientists speculate that this relatively soft rock (compared to others analyzed by *Spirit*) may have been modified by water. Small cracks in the surface outside the drill holes may be the result of interactions with water-rich fluids. In addition to searching for signs of water, the rovers are analyzing the chemical composition of the Martian surface to try to determine its history and its potential for supporting life.

NASA missions have revealed that water once flowed over Mars' surface. NASA also is studying the surface and Mars meteorites found on Earth for the presence of organic materials and chemical indicators of life. There may be present-day niches on Mars that are hospitable to life or specific deposits that have preserved chemicals that indicate that Martian life could have—or did—exist.

NASA'S PROGRESS AND ACHIEVEMENTS IN FY 2004

The Space Science Advisory Committee, an external advisory board, reviewed the progress of Outcomes 5.4.1 and 5.4.2 and determined that NASA successfully demonstrated progress in both Outcomes during FY 2004.

Outcome 5.4.1: Understand the character and extent of prebiotic chemistry on Mars.

The overarching goal of the Mars Science Laboratory rover, scheduled for launch in 2009, will be to explore and quantitatively assess the Martian surface as a habitat for life, past, present, or future. Its instruments will be capable of identifying organic compounds and its measurements will contribute to our evaluation of probable prebiotic chemistry on Mars. NASA released the solicitation for Mars Science Laboratory rover instruments in FY 2004.

Outcome 5.4.2: Search for chemical and biological signatures of past and present life on Mars.

NASA's progress included discoveries by the Mars Exploration Rovers and researching a shared system for samples collected on the Mars surface. The rover *Opportunity* discovered evaporite minerals suggesting at least one surface location that is promising for the search for past or present Martian life. This year, NASA also conducted a study to identify the issues and feasibility of a shared system for Mars surface sample preparation and distribution. The system would

Figure 93: The sun sets on Mars as the Mars Science Laboratory rover continues to explore in this artist concept. The mission is planned for launch in 2009.

provide common functions for: receiving a variety of sample types from multiple sample acquisition systems; conducting preliminary analysis of these samples with non-destructive science instruments and making decisions about what should happen to the samples; performing a variety of sample preparation functions; and, finally, sharing the prepared samples with additional science instruments for further analysis.

Performance Measures for Objective 5.4		2004 Rating	Past Years' Performance Measures and Ratings	2003	2002	2001
Outcome 5.4.1	Understand the character and extent of prebiotic chemistry on Mars.	green		Outcomes originated in FY 2004		
APG 4MEP13	Successfully demonstrate progress in investigating the character and extent of prebiotic chemistry on Mars. Progress towards achieving outcomes will be validated by external review.	green		none	none	none
Outcome 5.4.2	Search for chemical and biological signatures of past and present life on Mars.	green		Outcomes originated in FY 2004		
APG 4MEP14	Successfully demonstrate progress in searching for chemical and biological signatures of past and present life on Mars. Progress towards achieving outcomes will be validated by external review.	green		3S8 green	2S8 green	1S14 blue

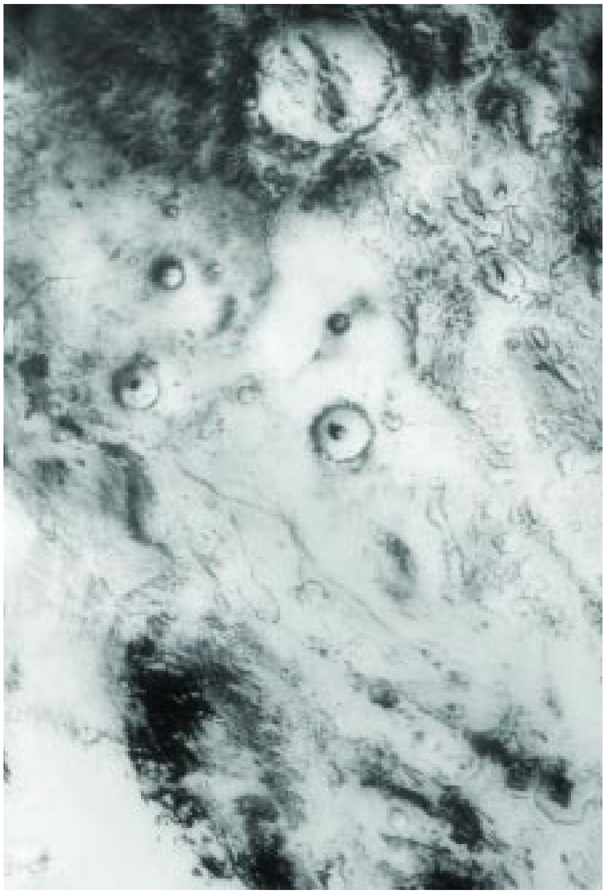
Goal 5
Explore the solar system and the universe beyond, understand the origin and evolution of life, and search for evidence of life elsewhere.

OBJECTIVE 5.5

Develop an understanding of Mars in support of future human exploration.

WHY PURSUE OBJECTIVE 5.5?

Mars is Earth's closest planetary neighbor, so of all of the Sun's planets, researchers can most easily explore Mars. NASA intends to send human missions to the Red Planet. Before a crew is sent, however, NASA is using robotic missions to identify useful resources and potential hazards. NASA Mars missions will perform a number of functions: characterize the distribution of water (both ice and liquid) from orbit and from on site analysis of local materials; analyze the space radiation environment on and around Mars; measure the Martian surface's mechanical properties; and study the composition of specific rocks and soils.



Credit: NASA JPL/Malin Space Science Systems

Figure 94: This Mars Global Surveyor image, taken with the Mars Orbiter Camera in late 2003, shows Mars' retreating seasonal southern polar cap. The bright areas are covered with frost and the dark areas are those from which the solid carbon dioxide has sublimed away. The image is illuminated by sunlight from the upper left.

NASA'S PROGRESS AND ACHIEVEMENTS IN FY 2004

The Space Science Advisory Committee, an external advisory board, reviewed the progress of Outcomes 5.5.1 and 5.5.2 and determined that NASA successfully demonstrated progress in both Outcomes during FY 2004. In both Outcomes, the Space Science Advisory Committee recommended a "blue" rating indicating exceptional achievement (e.g., results of major importance or significant unexpected discoveries), relative to resources invested in those research focus areas.

Outcome 5.5.1: Identify and understand the hazards that the Martian environment will present to human explorers.

NASA made exceptional progress in this Outcome by using the Mars Global Surveyor to look for current and future hazards. The Mars Global Surveyor team developed the ability to collect images of the Martian surface that identify objects smaller than 1 meter. This data proved useful in identifying hazards at the Mars Exploration Rover landing sites. NASA's Mars Reconnaissance Orbiter, which will launch in 2005, will provide a more extensive data set at similar resolution. The data obtained by the Mars Reconnaissance Orbiter could be used to select future human landing sites. In addition to assuring safe landing sites, the Mars Global Surveyor's Thermal Emission

Spectrometer observations are collecting the data necessary for researchers to understand middle-atmosphere winds and atmospheric profiles (i.e, pressure and density versus altitude), which are important during entry, descent, and landing on Mars. This data will benefit the design and operation of human flight systems.

Outcome 5.5.2: Inventory and characterize Martian resources of potential benefit to human exploration of Mars.

NASA's exceptional progress in this Outcome included developing an inventory of ice concentration in Martian soils. The Mars Odyssey team developed a seasonal inventory of ice concentration in soils at high latitudes, as well as an initial analysis of hydrogen enrichment (a likely indicator of OH-bearing minerals like hydroxides and/or hydrates) in soils at mid and equatorial latitudes. These results provide a basis for identifying water-rich locations on the surface of Mars. In addition, the discovery of water ice exposed on the Martian surface indicates clearly accessible resources for future human explorers.

Performance Measures for Objective 5.5		2004 Rating	Past Years' Performance Measures and Ratings	2003	2002	2001
Outcome 5.5.1	Identify and understand the hazards that the Martian environment will present to human explorers.	blue		Outcomes originated in FY 2004		
APG 4MEP15	Successfully demonstrate progress in identifying and studying the hazards that the Martian environment will present to human explorers. Progress towards achieving outcomes will be validated by external review.	blue		3S8 green	2S8 blue	none
Outcome 5.5.2	Inventory and characterize Martian resources of potential benefit to human exploration of Mars.	blue		Outcomes originated in FY 2004		
APG 4MEP16	Successfully demonstrate progress in inventorying and characterizing Martian resources of potential benefit to human exploration of Mars. Progress towards achieving outcomes will be validated by external review.	blue		3S8 green	2S8 blue	none

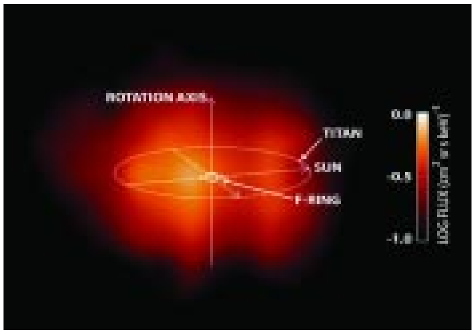
Goal 5 Explore the solar system and the universe beyond, understand the origin and evolution of life, and search for evidence of life elsewhere.

OBJECTIVE 5.6

Understand the changing flow of energy and matter throughout the Sun, heliosphere, and planetary environments.

WHY PURSUE OBJECTIVE 5.6?

Life on Earth prospers in a biosphere sustained by energy from the Sun. The Sun's energy output is constant when averaged over millennia, yet highly variable on an 11-year cycle and, sometimes, from second to second. The planets and moons of the solar system orbit within these inhospitable outer layers of the Sun's atmosphere. Some of these planetary bodies, like Earth, have an atmosphere and magnetic field that partially shield the surface from dangerous radiation and particles coming from the Sun and the galaxy beyond.



Credit: NASA JPL/JHU

Figure 95: Saturn's magnetosphere is seen for the first time in this image taken by the Cassini spacecraft on June 21, 2004. It is invisible to the human eye, but Cassini's Magnetospheric Imaging Instrument was able to detect the hydrogen atoms (represented in red) that escape it. The emission from these hydrogen atoms comes primarily from regions far from Saturn, well outside the planet's rings, and perhaps beyond the orbit of the largest moon, Titan.

NASA is studying the structure and dynamics of the Sun, its corona and solar wind, the origins of magnetic changes in the Sun and how these solar variations create disturbances with the Earth-Sun system. NASA is also seeking to understand how the diverse planetary magnetospheres and atmospheres respond to both internal and external influences and what this information can tell us about Earth's connection to the Sun. For example, determining how powerful flares and coronal mass ejection arriving at Earth can create powerful currents and radiation to disrupt telecommunications and navigation, threaten astronauts, damage satellites, and disable electric power grids, is a primary goal.

NASA'S PROGRESS AND ACHIEVEMENTS IN FY 2004

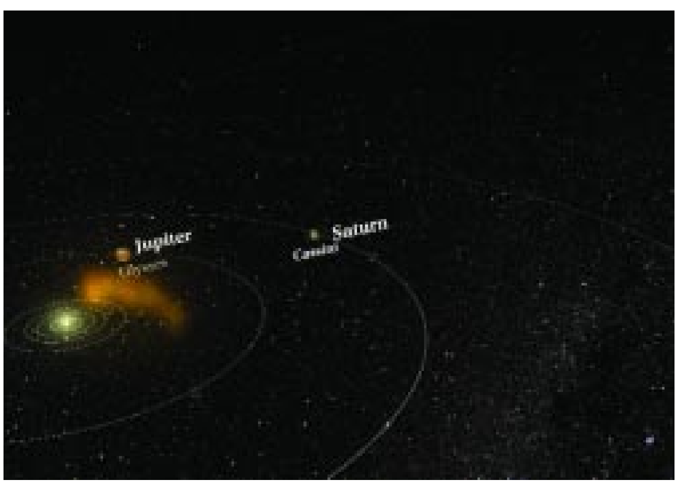
The Space Science Advisory Committee, an external advisory board, reviewed the progress of Outcomes 5.6.1 through 5.6.3 and determined that NASA successfully demonstrated progress in all three Outcomes during FY 2004. In Outcome 5.6.2, the Space Science Advisory Committee recommended a "blue" rating indicating exceptional achievement (e.g., results of major importance or significant unexpected discoveries), relative to resources invested in those research focus areas.

Outcome 5.6.1: Understand the structure and dynamics of the Sun and solar wind and the origins of magnetic variability.

In FY 2004, NASA learned more about solar "pre-flares," the variable speeds of solar wind, and coronal mass ejections (huge bubbles of gas ejected from the Sun). The Ramaty High Energy Solar Spectroscopic Imager obtained the most detailed and broadest range spectra observations of the Sun's light, broken into its component colors. These observations help scientists determine what processes develop in which layers of the Sun. The Imager also discovered a sizeable population of X-ray-emitting electrons, high in the corona, about ten minutes before a solar flare. These "preflare" electrons contained as much energy as those accelerated during the main solar flare, implying that substantial energy is released in solar eruptions much earlier than previously thought. Meanwhile, NASA's Ulysses and the Transition Region and Coronal Explorer spacecraft are helping scientists understand why hotter, brighter, and more radiative regions generate slow solar wind while cooler, darker regions like coronal holes generate fast wind. Researchers working with the Solar and Heliospheric Observatory validated new computational methods for the promising technique of time-distance helioseismology (detecting magnetic flux below the Sun's surface before it erupts into sunspots, flares, and coronal mass ejections). This development is crucial for predicting the emergence of solar active regions from ground observatories. Solar and Heliospheric Observatory researchers also developed techniques for constructing three-dimensional descriptions of coronal mass ejections, the primary cause of the most violent space weather. Measuring the three-dimensional structure of coronal mass ejections is vital for understanding how the eruptions begin and how they evolve as they propagate in the solar wind.

Outcome 5.6.2: Determine the evolution of the heliosphere and its interaction with the galaxy.

In Fall 2003, a large cluster of active regions on the Sun produced a series of solar flares and coronal mass ejections that caused a series of blast waves to radiate through the solar system. NASA's fleet of satellites throughout the solar system observed for the first time the progress and timing of the blast waves as they rushed through the solar system and pushed the solar system boundary 1.5 billion miles deeper into interstellar space, expanding the volume of the Sun's corner of the galaxy by almost a third. The storms produced deadly particle radiation equal to one-half of the total emitted from the Sun in the last ten years and affected satellite operations from Earth to Mars. Meanwhile, on the outer edges of the solar system, Voyager-1, now roughly 90 times farther from the Sun than is the Earth, continues to detect dramatic changes in high-energy particles, signaling its proximity to the outer boundary of the solar wind. Voyager-1's observations reflect the ebb and flow of the edge of the solar system as it recedes and overtakes NASA spacecraft and so is revealing previously unknown dynamics of the solar system's interaction with the galaxy. NASA researchers also discovered some anomalous cosmic rays resulting from interactions with dust grains from the Kuiper Belt, a region of remnants located past Neptune, left over from the formation of the solar system. The discovery that these anomalous cosmic rays can be generated from material in the Kuiper Belt provides a path for understanding the Belt's size, composition, and processes.



Credit: NASA/Walt Feimer

Figure 96: The Sun regularly sends massive solar explosions of radiative plasma with the intensity of a billion megaton bombs hurtling through the solar system. NASA spacecraft observed such an event that began in October 2003, passed the Ulysses and Cassini spacecraft near Jupiter and Saturn in November, and reached the Voyager spacecraft at the edge of the solar system in June 2004.

Outcome 5.6.3: Understand the response of magnetospheres and atmospheres to external and internal drivers.

Activities contributing to NASA's progress included making new comparisons between planetary environments and learning more about Earth's magnetopause (the magnetic boundary between the Earth's field and the solar wind) and the atmospheres of other planets. NASA's satellites and orbiting telescopes made observations of Mars, Saturn, Jupiter, and Jupiter's moon, Io, and revealed information under a range of conditions not available on Earth. An investigation at Mars and Earth revealed that solar energy accounts for the basic variability in both Mars' and Earth's ionospheres. The Hubble Space Telescope imaged Saturn's aurora while Cassini collected radio measurements and images of the high-energy particles revealing that the magnetosphere of Saturn, like that of the Earth, is strongly affected by changes in the solar wind. This is surprisingly different from the magnetosphere of Jupiter, which appears to be internally powered. Cassini also detected plasma bubble structures at the edge of the Io torus, a giant doughnut-shaped gaseous ring around Jupiter. The discovery is helping NASA understand similar smaller scale structures called spread-F irregularities on Earth. At Jupiter, NASA's Ulysses' Jupiter Distant Encounter detected dust streams from Jupiter's magnetosphere at unexpectedly large distances and latitudes indicating that the heliospheric magnetic field is deflecting the electrically charged dust streams. Studying the behavior of dust streams and their interactions with magnetic fields is providing new insight on moon and planet formation.

Closer to Earth, five satellites, (1) the Polar; (2) the Cluster; (3) the Fast Auroral Snapshot Explorer; (4) the Imager for Magnetopause-to-Aurora Global Exploration; and (5) the Advanced Composition Explorer, continued to advance researchers' knowledge of planetary magnetopauses with new discoveries of large electric fields at the magnetopause boundary and the continuous presence of a large opening in the Earth's magnetic shield that let solar wind pour into the Earth's atmosphere. The satellites also revealed that the Earth's inner plasmasphere (part of Earth's magnetic field) rotates at a rate 10-15 percent slower than the solid Earth's rotation rate. Also, the Thermosphere, Ionosphere, Mesosphere, Energetics and Dynamics mission revealed that Earth's upper atmosphere temperatures are driven directly by the Sun. Researchers also confirmed the existence of a "natural thermostat" that regulates upper atmospheric temperatures during solar storms, cooling them to pre-storm levels in a matter of days. Without this mechanism, cooling to pre-storm levels would require seven to ten days, which is longer than the time between disturbances. Researchers also confirmed predictions that a chemical reaction between atomic hydrogen and ozone is the major source of heat near the mesopause, the uppermost region of the mesosphere that is located 50-80 kilometers above the Earth's surface.

Performance Measures for Objective 5.6		2004 Rating	Past Years' Performance Measures and Ratings	2003	2002	2001
Outcome 5.6.1	Understand the structure and dynamics of the Sun and solar wind and the origins of magnetic variability.	green		Outcomes originated in FY 2004		
APG 4SEC11	Successfully demonstrate progress in understanding the structure and dynamics of the Sun and solar wind and the origins of magnetic variability. Progress towards achieving outcomes will be validated by external review.	green		3S7 green	2S7 green	none
Outcome 5.6.2	Determine the evolution of the heliosphere and its interaction with the galaxy.	blue		Outcomes originated in FY 2004		
APG 4SEC12	Successfully demonstrate progress in determining the evolution of the heliosphere and its interaction with the galaxy. Progress towards achieving outcomes will be validated by external review.	blue		none	none	none
Outcome 5.6.3	Understand the response of magnetospheres and atmospheres to external and internal drivers.	green		Outcomes originated in FY 2004		
APG 4SEC13	Successfully demonstrate progress in understanding the response of magnetospheres and atmospheres to external and internal drivers. Progress towards achieving outcomes will be validated by external review.	green		none	none	none

Goal 5
Explore the solar system and the universe beyond, understand the origin and evolution of life, and search for evidence of life elsewhere.

OBJECTIVE 5.7

Understand the fundamental physical processes of space plasma systems.

WHY PURSUE OBJECTIVE 5.7?

The seemingly empty void between objects in the solar system is actually filled with a complex web of magnetic fields that interact and transfer energy across the heliosphere, the region of space influenced by the Sun. NASA seeks to discover how solar and planetary magnetic fields are created and evolve; how they produce heat and high-energy particles; and how to create, destroy, and reconnect magnetic fields. NASA's space plasma research focuses on understanding how and why processes that occur on very small scales generally affect large-scale global dynamics. This interaction across multiple scale lengths is important for understanding instabilities and turbulence in all space plasmas. The solar system offers the opportunity to test scientific understanding of these processes in diverse plasma environments.

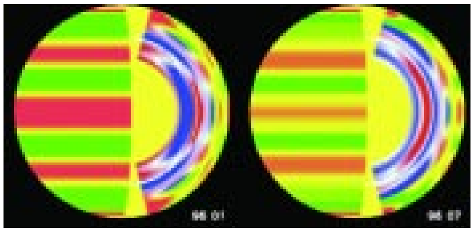


Figure 97: Currents of gas deep inside the Sun pulsate like the blood in human arteries, speeding and slackening every 16 months. Located about 135,000 miles below the solar surface, the tachocline separates the sun's two major regions of gas: the radiative zone, which includes the energy-generating core, and the convection zone near the surface. Measurements taken by the Solar and Heliospheric Observatory spacecraft indicate that the 11-year sunspot cycle originates in this area where electrically charged gases generate a magnetic field.

NASA'S PROGRESS AND ACHIEVEMENTS IN FY 2004

The Space Science Advisory Committee, an external advisory board, reviewed the progress of Outcomes 5.7.1 and 5.7.2 and determined that NASA successfully demonstrated progress in both Outcomes during FY 2004.

Outcome 5.7.1: Discover how magnetic fields are created and evolve and how charged particles are accelerated.

NASA conducted research to understand: magnetic reconnection, particle acceleration, radio emissions called "auroral roar," and movements going on below the Sun's surface. The Cluster, Polar, Geotail, and Wind missions resolved several uncertainties associated with magnetic reconnection, a process that occurs in magnetic fields where magnetic lines of force are broken and reconnected in a different way, liberating magnetic energy into other forms such as kinetic energy, heat and light. Researchers observing the Earth's bow shock (the area where the solar wind meets the Earth's protective magnetic field, the magnetosphere) settled a long-standing debate about the sources of ion beams and the basic properties of particle acceleration at the bow shock. Shocks serve as natural particle accelerators throughout the universe and are an important source of galactic cosmic rays. Researchers also answered some long-standing questions about the source of a radio emission called "auroral roar" that can be detected in regions that experience auroras on Earth. Researchers used a High-Bandwidth Auroral Rocket to penetrate the source region and measured the detailed spectrum of the emissions. The rocket confirmed the presence of electric waves with characteristics similar to those predicted by current theories. Finally, the Solar and Heliospheric Observatory measurements of subsurface motions on the Sun revealed that the 11-year sunspot cycle originates in a very thin shell called the tachocline, a region of intense shear motion about a third of the way down into the solar interior where the magnetic field is confined and amplified. The measurements explain the occurrence of long-lived nests of solar activity and the synchronization of the Sun's northern and southern hemisphere activity cycles.

Outcome 5.7.2: Understand coupling across multiple scale lengths and its generality in plasma systems.

FY 2004 initiatives contributed to researchers' increased understanding of the effects of solar heating on the thermosphere (the uppermost thermal layer of the atmosphere) and the coupling of different effects in the solar wind. Using the Thermosphere, Ionosphere, Mesosphere, Energetics, and Dynamics instrument, NASA researchers revealed the upward movement, into the thermosphere, of waves generated by latent heating. A similar calculation for Mars demonstrated that these effects on the upper atmosphere of Mars are even greater than that on Earth. NASA also launched its first extended "horizontal-trajectory" sounding rocket flight and discovered that auroral arcs (luminous bands elongated in an east-west direction) do not drive upper atmospheric winds and play little role in thermospheric mixing. NASA researchers also revealed a new understanding of the coupling between turbulence, shear and energetic particles in the solar wind. This expands understanding of heliospheric structure, basic plasma physics, and charged particle transport theory.

Performance Measures for Objective 5.7		2004 Rating	Past Years' Performance Measures and Ratings	2003	2002	2001
Outcome 5.7.1	Discover how magnetic fields are created and evolve and how charged particles are accelerated.	green		Outcomes originated in FY 2004		
APG 4SEC14	Successfully demonstrate progress in discovering how magnetic fields are created and evolve and how charged particles are accelerated. Progress towards achieving outcomes will be validated by external review.	green		none	none	none
Outcome 5.7.2	Understand coupling across multiple scale lengths and its generality in plasma systems.	green		Outcomes originated in FY 2004		
APG 4SEC15	Successfully demonstrate progress in understanding coupling across multiple scale lengths and its generality in plasma systems. Progress towards achieving outcomes will be validated by external review.	green		none	none	none

Goal 5
Explore the solar system and the universe beyond, understand the origin and evolution of life, and search for evidence of life elsewhere.

OBJECTIVE 5.8

Learn how galaxies, stars, and planetary systems form and evolve.

WHY PURSUE OBJECTIVE 5.8?

Today, the universe is a structured place, filled with giant galaxies of stars and planetary bodies. This structure emerged several hundred million years after the Big Bang from a nearly formless sea of matter and radiation. NASA is seeking to determine how this sea of formless matter organized into complex forms of matter and energetic processes that produced the first stars and galaxies, how different galactic systems of stars and gas form, and which of these systems can lead to planets and living organisms. NASA scientists are tracing the condensation of gas and dust into stars and planets and detecting planetary systems around other stars with the ultimate goal of understanding planetary systems and their evolution. NASA is learning how the life cycle of stars creates the chemical elements needed for planets and life and trying to determine if there is a region in the Milky Way that is especially suited to the development of life—a "galactic habitable zone." Current and future space observatories are capturing the birth of stars and the emergence of planets from disks of ice and dust and providing glimpses of distant objects formed when the universe was young.

Credit: NASA/JPL-Caltech/G. Melnick, Harvard-Smithsonian CfA

Figure 98: In this false-color image taken on October 23, 2003, the Spitzer Space Telescope captures a microcosm of star formation in a cloudy region called Sharpless 140, which lies in constellation Cepheus. The red bowl shape traces the outer surface of the dense dust cloud encasing young stars.

NASA'S PROGRESS AND ACHIEVEMENTS IN FY 2004

The Space Science Advisory Committee, an external advisory board, reviewed the progress of Outcomes 5.8.1 through 5.8.4 and determined that NASA successfully demonstrated progress in all four Outcomes during FY 2004. In two of the Outcomes (5.8.1 and 5.8.4), the Space Science Advisory Committee recommended a "blue" rating indicating exceptional achievement (e.g., results of major importance or significant unexpected discoveries) relative to resources invested in those research focus areas.

Outcome 5.8.1: Learn how the cosmic web of matter organized into the first stars and galaxies and how these evolved into the stars and galaxies we see today.

NASA's exceptional progress in this Outcome included observations from the Hubble Space Telescope and the Galaxy Evolution Explorer and insight into the formation of the first stars in the Universe. Using observations from the Hubble Space Telescope, researchers unveiled the deepest portrait of the visible universe ever achieved. The new portrait, called the Hubble Ultra Deep Field, revealed the first galaxies to emerge from the so-called "dark ages," the time shortly after the Big Bang when the first stars reheated the cold, dark universe. The new image should offer new insights into what types of objects reheated the universe long ago. Researchers also compared the catalogs of distant galaxies in the Hubble Ultra Deep Field and in the Great Observatories Origins Deep Survey to gain insight into the early processes that may have been responsible for some or all of the re-ionization of hydrogen in the early universe. Through this process, the first stars in the universe grouped in proto-galaxies and created small transparent regions around them. These regions increased in size until the neighboring regions merged together and cleared up the “fog” of neutral hydrogen making the universe transparent to star light as it is now). In FY 2004, the Galaxy Evolution Explorer, which will study the rate of star formation in the local universe, began full science operations and received

Credit: NASA/JPL/Caltech

Figure 99: The Galaxy Evolution Explorer (GALEX) celebrated the first anniversary of its launch on April 23, 2003, with this image of a pair of galaxies 10 million light-years away. The galaxies are M81, similar in size and brightness to the Milky Way, and M82, where stars are violently forming and expelling gas and dust out perpendicular to its disk.

some initial results. Researchers also used observations from the Wilkinson Microwave Anisotropy Probe and the Sloan Digital Sky Survey to stimulate a significant amount of theoretical work on the first stars in the universe, leading to the belief that the formation of the first stars was a prolonged process.

Outcome 5.8.2: Understand how different galactic ecosystems of stars and gas formed and which ones might support the existence of planets and life.

Achievements contributing to NASA’s progress included new observations from the Chandra X-Ray facility and the Galaxy Evolution Explorer. Researchers using the Chandra X-ray Observatory discovered rich deposits of neon, magnesium, and silicon in a pair of colliding galaxies known as The Antennae. According to theory, when the clouds in which these elements are present cool, an exceptionally high number of stars with planets should form. The amount of enrichment of elements in The Antennae is high due to a very high rate of supernova explosions in these colliding galaxies. When galaxies collide, direct hits between stars are extremely rare, but collisions between huge gas clouds in the galaxies can trigger a stellar formation burst. The most massive of these stars race through their evolution in a few million years and explode as supernovas. Heavy elements manufactured inside these stars are blown away by the explosions and enrich the surrounding gas for thousands of light years. A number of studies indicate that clouds enriched in heavy elements are more likely to form stars with planetary systems, so in the future, an unusually high number of planets may form in The Antennae. Observations from the Galaxy Evolution Explorer also revealed striking images of star formation. (The Galaxy Evolution Explorer large-format detectors were developed under the sub-orbital program over many years and are providing a spectacular return on the original investment.)

Outcome 5.8.3: Learn how gas and dust become stars and planets.

NASA researchers used the Far Ultraviolet Spectroscopic Explorer and the Hubble Space Telescope to observe HR 4796A, a nearby 8 million year old main-sequence star surrounded by a dusty disk that may form planets in that system. Researchers looked for significant amounts of elements heavier than hydrogen, but failed to detect any of these species. These measurements suggest that this stellar system possesses very little molecular gas and may not be able to form a planet as big as Jupiter. The Spitzer Space Telescope successfully completed in-orbit checkout and began science operations. Since it began operations, Spitzer has discovered hundreds of protostars in high mass star forming regions. These observations will provide quantitative information on the rapid and rare formation process of stars heavier than the Sun. Delays with the Stratospheric Observatory for Infrared Astronomy slowed its deployment. When deployed, the observatory has the potential to have a major impact on scientists’ understanding of star formation.

Outcome 5.8.4: Observe planetary systems around other stars and compare their architectures and evolution with our own.

NASA-funded researchers discovered the most distant object orbiting the Sun. The object is a mysterious planet-like body three times farther from Earth than Pluto. The object, called “Sedna” for the Inuit goddess of the ocean, is 8 billion miles away in the farthest reaches of the solar system. This is likely the first detection of the long-hypothesized Oort cloud, a repository of small icy bodies on the fringe of the solar system that supplies the comets that streak by Earth. Other notable features of Sedna include its size and reddish color. After Mars, it is the second reddest object in the solar system. It is estimated Sedna is approximately three-fourths the size of Pluto. Sedna is likely the largest object found in the solar system since Pluto was discovered in 1930. Sedna is extremely far from the Sun, in the coldest known region of the solar system, where temperatures never rise above minus 400 degrees Fahrenheit. In another finding, the Spitzer Space Telescope surveyed a group of young stars and found intriguing evidence that one of them may have the youngest planet detected. The observatory found a clearing in the disk around the star CoKu Tau 4. This might indicate that an orbiting planet swept away the disk material. The new findings reveal the structure of the gap more clearly than ever. CoKu Tau 4 is only about one million years old; the possible new planet would be even younger. In comparison, the Earth is approximately 4.5 billion years old.

Performance Measures for Objective 5.8		2004 Rating	Past Years' Performance Measures and Ratings	2003	2002	2001
Outcome 5.8.1	Learn how the cosmic web of matter organized into the first stars and galaxies and how these evolved into the stars and galaxies we see today.	blue		Outcomes originated in FY 2004		
APG 4ASO9	Successfully demonstrate progress in learning how the cosmic web of matter organized into the first stars and galaxies and how these evolved into the stars and galaxies we see today. Progress towards achieving outcomes will be validated by external review.	blue		3S3 green	2S3 green	none
Outcome 5.8.2	Understand how different galactic ecosystems of stars and gas formed and which ones might support the existence of planets and life.	green		Outcomes originated in FY 2004		
APG 4ASO10	Successfully demonstrate progress in understanding how different galactic ecosystems of stars and gas formed and which ones might support the existence of planets and life. Progress towards achieving outcomes will be validated by external review.	green		none	none	none
Outcome 5.8.3	Learn how gas and dust become stars and planets.	green		Outcomes originated in FY 2004		
APG 4ASO11	Successfully demonstrate progress in learning how gas and dust become stars and planets. Progress towards achieving outcomes will be validated by external review.	green		3S3 green	2S3 green	none
Outcome 5.8.4	Observe planetary systems around other stars and compare their architectures and evolution with our own.	blue		Outcomes originated in FY 2004		
APG 4ASO12	Successfully demonstrate progress in observing planetary systems around other stars and comparing their architectures and evolution with our own. Progress towards achieving outcomes will be validated by external review.	blue		3S4 blue	2S4 green	none

Goal 5
Explore the solar system and the universe beyond, understand the origin and evolution of life, and search for evidence of life elsewhere.

OBJECTIVE 5.9

Understand the diversity of worlds beyond our solar system and search for those that might harbor life.

WHY PURSUE OBJECTIVE 5.9?

After centuries of speculation, scientists now know that there are planets orbiting other stars. The extrasolar planets discovered so far seem to be gas giants like Jupiter. Earth-like worlds also may orbit other stars, but until now, the resources used to search for planets lacked the precision needed to detect a world as small as Earth.

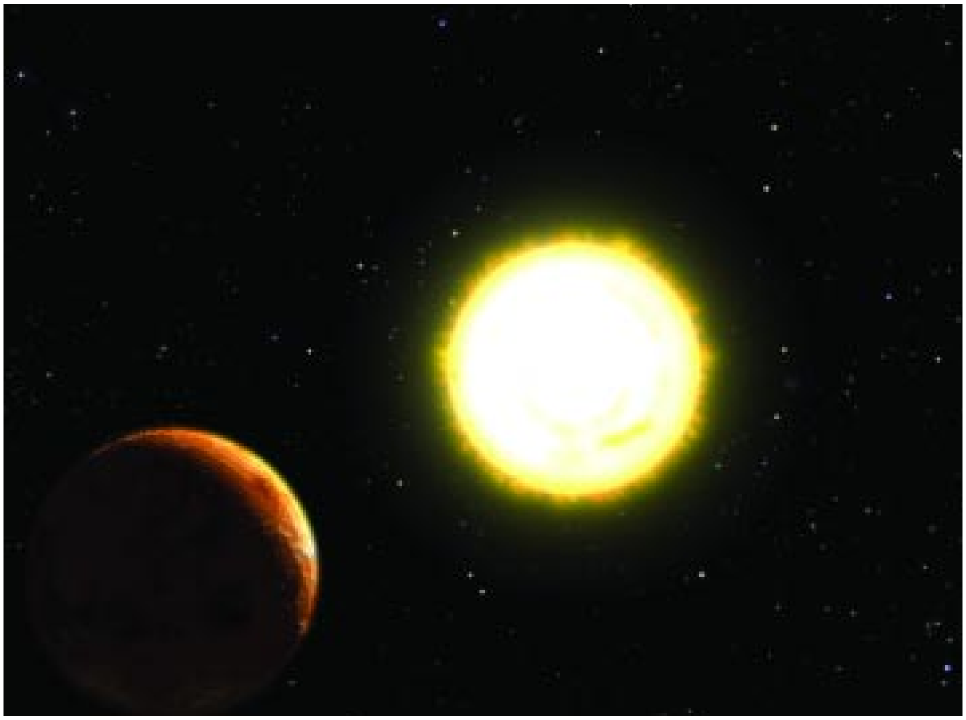


Figure 100: This artist's concept shows a Neptune-sized planet—one of the smallest extrasolar planets found to date—orbiting 55 Cancri, a star in the constellation Cancer. The planet was one of two newly found Neptune-sized planets (the other circles M dwarf star Gliese 436) announced on August 31, 2004, by Paul Butler (Carnegie Institute of Washington) and Geoffrey Marcy (University of California, Berkeley), a planet-finding team funded by NASA and the National Science Foundation.

NASA is moving toward finding extrasolar, Earth-like planets and, ultimately, life beyond this solar system. Along the way, NASA is discovering the nature and properties of giant planets orbiting other stars and which of them might be hospitable to life. Detailed studies of giant planets will tell scientists much about the formation and history of planetary systems.

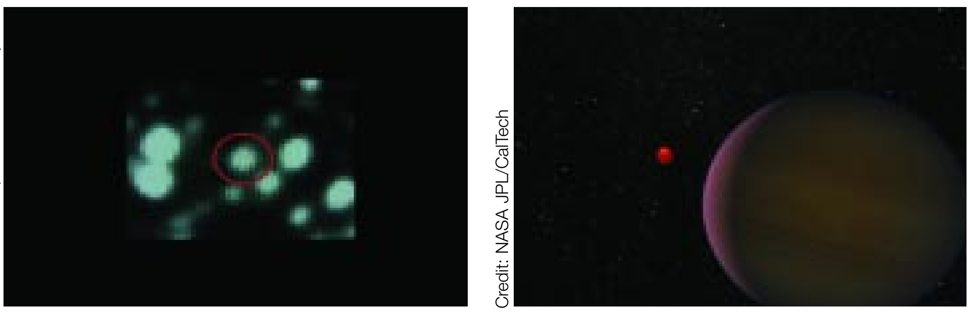
NASA's space observatories allow scientists to analyze atmospheric properties of these distant giants, even if they cannot observe the planet directly. Once NASA has found terrestrial planets orbiting nearby stars, the Agency can tackle the ambitious tasks of determining which planets have conditions suitable for life and which, if any, show actual signs of past or present life. Scientists also are developing ways to identify "biosignatures," identifiable spectral features in a planet's reflected light that can reveal past or present life on a planet.

NASA'S PROGRESS AND ACHIEVEMENTS IN FY 2004

The Space Science Advisory Committee, an external advisory board, reviewed the progress of Outcomes 5.9.1 through 5.9.4 and determined that NASA successfully demonstrated progress in all four Outcomes during FY 2004. In Outcome 5.9.4, the Space Science Advisory Committee recommended a "blue" rating indicating exceptional achievement (e.g., results of major importance or significant unexpected discoveries) relative to resources invested in those research focus areas.

Outcome 5.9.1: Characterize the giant planets orbiting other stars.

NASA astronomers created computer models of planets orbiting stars that match the data from two known systems (HD209458b and OGLE-TR-56b). These models demonstrate that astronomers now possess a good understanding of the relationships between the characteristics observed in extrasolar planets and the stars they orbit. NASA-funded theoretical work also produced new spectra and structural models of OGLE-TR-56b which is larger than Jupiter, but extremely close to its parent star. These models will help NASA understand the limits and characteristics of planets exposed to such intense radiation.



Credit: Las Campanas Observatory

Credit: NASA JPL/CalTech

Figure 101: In April 2004, astronomers for the first time found a planet circling a star outside the solar system using gravitational microlensing, shown in this artist's concept on the right. The picture on the left was taken at Warsaw telescope at Las Campanas Observatory, Chile. Although this planet is one and a half times larger than Jupiter, astronomers believe that the importance of gravitational microlensing is its ability to find small-mass planets similar in size to Earth.

Outcome 5.9.2: Find out how common Earth-like planets are and see if any might be habitable.

For the first time, researchers discovered an extra solar planet using gravitational microlensing. In gravitational microlensing, a star or planet acts as a cosmic lens to magnify and brighten a more distant star lined up behind it. The gravitational field of the foreground star bends and focuses light, like a glass lens bending and focusing starlight in a telescope. Albert Einstein predicted this effect in his theory of general relativity and confirmed it with the Sun. Two international research teams cooperated to make the discovery: Microlensing Observations in Astrophysics and the Optical Gravitational Lensing Experiment (funded by NASA and the National Science Foundation). The newly discovered star-planet system is 17,000 light years away, in the constellation Sagittarius. The planet, orbiting a red dwarf parent star, is most likely one-and-a-half times bigger than Jupiter. The planet and star are three times farther apart than Earth and the Sun.

Outcome 5.9.3: Trace the chemical pathways by which simple molecules and dust evolve into the organic molecules important for life.

Spitzer Space Telescope observations of young stars in the Taurus cloud revealed significant amounts of icy organic materials sprinkled throughout several "planetary construction zones" or dusty planet-forming discs that circle infant stars. These materials, icy dust particles coated with water, methanol, and carbon dioxide, may help explain the origin of icy planetoids like comets. Previous studies identified similar organic materials in space, but this is the first time they were seen clearly in the dust making up planet forming discs. NASA researchers also made progress in tracing the link between ice processes and the organic molecules in meteorites by theorizing that some of the interesting organic compounds found in meteorites may have formed in presolar ice and were not a product of water existing on the original source of the meteorite (i.e., planet, comet, asteroid). Scientists previously demonstrated that ultraviolet radiation can break down chemicals in ice left over from the formation of the Solar System, so called presolar ice, producing amino acids, the building blocks of life. Researchers also found proof of organic compounds in the Murchison meteorite that fell in Murchison, Victoria, Australia in 1969. The meteorite contained a wide variety of organic compounds and showed that many organic molecules can be formed in space. This discovery raised the possibility that such extraterrestrial material might have played a role in the origin of life.

Outcome 5.9.4: Develop the tools and techniques to search for life on planets beyond our solar system.

Activities contributing to NASA's exceptional progress in this Outcome included developing methods for imaging Earth-like extra-solar planets and detecting the biological signs of life in extra solar planetary atmospheres and interstellar space. NASA researchers developed and tested techniques like star-light suppression for observing faint planets near bright stars and theoretical advances in coronagraph design. (A coronagraph is a telescope that can see things very close to a star, like the Sun). These advances suggest that NASA now has the technology needed to directly image Earth-like planets around nearby stars. NASA researchers also used laboratory measurements of organic molecules found in interstellar space to identify promising potential astronomical observations for detecting biological precursor molecules in interstellar space in this Galaxy. NASA also continues to study and model Earth-like planetary atmospheres around stars of different temperatures to assess the detectability of global signs of life.

Performance Measures for Objective 5.9		2004 Rating	Past Years' Performance Measures and Ratings	2003	2002	2001
Outcome 5.9.1	Characterize the giant planets orbiting other stars.	green		Outcomes originated in FY 2004		
APG 4ASO13	Successfully demonstrate progress in characterizing the giant planets orbiting other stars. Progress towards achieving outcomes will be validated by external review.	green		3S4 blue	2S4 green	none
Outcome 5.9.2	Find out how common Earth-like planets are and see if any might be habitable.	green		Outcomes originated in FY 2004		
APG 4ASO14	Successfully demonstrate progress in finding out how common Earth-like planets are and seeing if any might be habitable. Progress towards achieving outcomes will be validated by external review.	green		none	none	none
Outcome 5.9.3	Trace the chemical pathways by which simple molecules and dust evolve into the organic molecules important for life.	green		Outcomes originated in FY 2004		
APG 4ASO15	Successfully demonstrate progress in tracing the chemical pathways by which simple molecules and dust evolve into the organic molecules important for life. Progress towards achieving outcomes will be validated by external review.	green		3S6 green	2S6 green	none
Outcome 5.9.4	Develop the tools and techniques to search for life on planets beyond our solar system.	blue		Outcomes originated in FY 2004		
APG 4ASO16	Successfully demonstrate progress in developing the tools and techniques to search for life on planets beyond our solar system. Progress towards achieving outcomes will be validated by external review.	blue		3S4 blue 3S6 green	2S4 green 2S6 green	none none

Goal 5 Explore the solar system and the universe beyond, understand the origin and evolution of life, and search for evidence of life elsewhere.

OBJECTIVE 5.10

Discover what powered the Big Bang and the nature of the mysterious dark energy that is pulling the Universe apart.

WHY PURSUE OBJECTIVE 5.10?

Although Einstein's General Theory of Relativity predicted the expansion of the universe, it did not explain the causes of this expansion. Today NASA has strong evidence that within the first infintesimal fraction of a second of its existence, the universe "inflated" its size enormously, producing a spacious arena for stars, galaxies, and the evolution of life. The underlying force behind this inflationary epoch is still not known, and is one of the most important questions related to the history of the universe. By one second after the beginning of time, with its inflation completed, the universe was again expanding in accord with Einstein, gradually slowing its expansion rate due to the attractive force of gravity generated by the universe's mass. Very recently, however, NASA has learned that some billions of years ago the universe started to accelerate its expansion, as though some form of anti-gravity were at work. Indeed, Einstein's theory allowed for the existence of a "dark energy" that uniformly pervades all of space which has this effect, and such dark energy is now known to exist. Its orgin, however, is completely unknown. Solving the mystery of dark energy is considered to be the most important task not only of cosmology, but also of particle physics.

Credit: Optical: NOAO/Kitt Peak/J.Uson, D.Dale; X-ray: NASA/CXC/IoA;S.Allen, et al.

Figure 102: Astronomers have detected and probed dark energy by applying a powerful, new method that uses images of galaxy clusters made by NASA's Chandra X-ray Observatory, like this composite image of galaxy cluster Abell 2029 from May 2004. The results trace the transition of the expansion of the universe from a decelerating to an accelerating phase several billion years ago, and give intriguing clues about the nature of dark energy and the fate of the universe.

The growth, shape, size, and destiny of the universe are determined by a tug-of-war among visible matter, dark matter, and dark energy. Dark matter, which constitutes 23 percent of the universe, is an as-yet unidentified form of matter. The only part of the universe humans really understand is visible matter (atoms), just four percent of the universe! NASA's current and future missions will help to increase understanding of the other 96 percent, by providing insights into the nature of dark matter and dark energy and their effects on the formation of clusters of galaxies, and on the ultimate destiny of the universe. NASA missions will also probe to the beginning of time, to view directly the inflation that made the universe as big as it is.

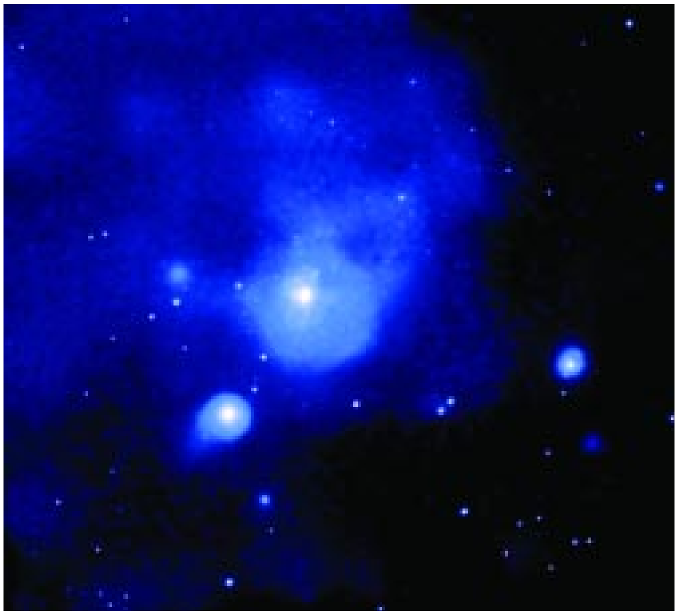
NASA'S PROGRESS AND ACHIEVEMENTS IN FY 2004

The Space Science Advisory Committee, an external advisory board, reviewed the progress of Outcomes 5.10.1 through 5.10.3 and determined that NASA successfully demonstrated progress in all three Outcomes during FY 2004. In Outcome 5.10.3, the Space Science Advisory Committee recommended a "blue" rating indicating exceptional achievement (e.g., results of major importance or significant unexpected discoveries) relative to resources invested in those research focus areas.

Outcome 5.10.1: Search for gravitational waves from the earliest moments of the Big Bang.
This year, NASA got a better look at the cosmic microwave background (a telltale remnant of the early universe), working toward a closer look at the Big Bang and establishing a multi-agency task force on cosmic microwave background research. The first two years of data from the Wilkinson Microwave Anisotropy Probe provided the first look at the full-sky polarization of the cosmic microwave background. NASA also selected a concept study for the Big Bang Observer, the goal of which is to observe directly the primordial gravitational waves that were produced at the beginning of time. Of all waves and particles known to physics, gravitational waves interact the least. So, they carry information undisturbed from the earliest moments of the universe, helping to elucidate its origin. NASA also worked with the National Science Foundation and the Department of Energy to establish an Interagency Task Force for Cosmic Microwave Background Research. The task force will provide a roadmap for the technology development required for a space mission to obtain the definitive polarization map of the cosmic microwave background.

Outcome 5.10.2: Determine the size, shape, and matter-energy content of the Universe.
NASA successfully demonstrated progress in this Outcome by continuing operation of the Wilkinson Microwave Anisotropy Probe mission at the L2 Lagrange point (a point in space where the gravitational pull of the Earth and the Sun cancel each other out creating a relatively stable home for a spacecraft). Also, significant progress was made by the Wilkinson Microwave Anisotropy Probe team toward constructing the first full-sky map of the cosmic microwave background polarization. This tremendous achievement is expected to reach completion in early FY 2005. The map will improve our determination of the cosmological parameters that dictate the state of the universe and improve our understanding of the very early history of the universe.

Outcome 5.10.3: Measure the cosmic evolution of dark energy.
Using the Hubble Space Telescope, NASA researchers discovered 42 new supernovae, including six of the seven most distant known. (Supernovae are caused when super-massive stars collapse, producing some of the most energetic explosions in the universe). Using these supernovae as "standard candles," of known luminosity, researchers confirmed the existence of dark energy and placed new limits on dark energy's time variability. Using Chandra, researchers also studied 26 distant galaxy clusters between one and eight billion years away tracing back in time to when the universe began to accelerate. Those findings corroborated the existence of dark energy. NASA and the Department of Energy began the formation of a science definition team for the NASA/Department of Energy Joint Dark Energy Mission. The science definition team will help assure the optimum scientific return from a dark energy space mission. Also, NASA researchers used the XMM Newton satellite to survey distant clusters of galaxies and found puzzling differences between today's clusters of galaxies and those present in the Universe about seven billion years ago. The results show that clusters of galaxies in the distant Universe seem to produce more X-rays than today, indicating that these clusters have changed their appearance with time. This finding will have an impact on using clusters as a probe of the existence of dark energy.



Credit: NASA/CXC/Comubia Univ./C. Scharf et al.

Figure 103: A Chandra X-Ray Observatory mosaic of images of the Fornax galaxy cluster reveals that the vast cloud of ten-million-degree Celsius gas surrounding the cluster core has a swept-back cometary shape that extends for more than half a million light years. Fornax is just one of the many clusters that Chandra imaged this fiscal year.

Performance Measures for Objective 5.10		2004 Rating	Past Years' Performance Measures and Ratings: 2003	2002	2001
Outcome 5.10.1	Search for gravitational waves from the earliest moments of the Big Bang.	green	Outcomes originated in FY 2004		
APG 4SEU9	Successfully demonstrate progress in search for gravitational waves from the earliest moments of the Big Bang. Progress towards achieving outcomes will be validated by external review.	green	none	none	none
Outcome 5.10.2	Determine the size, shape, and matter-energy content of the universe.	green	Outcomes originated in FY 2004		
APG 4SEU10	Successfully demonstrate progress in determining the size, shape, and matter-energy content of the universe. Progress towards achieving outcomes will be validated by external review.	green	3S1 blue	2S1 green	none
Outcome 5.10.3	Measure the cosmic evolution of dark energy.	blue	Outcomes originated in FY 2004		
APG 4SEU11	Successfully demonstrate progress in measuring the cosmic evolution of the dark energy, which controls the destiny of the universe. Progress towards achieving outcomes will be validated by external review.	blue	none	none	none

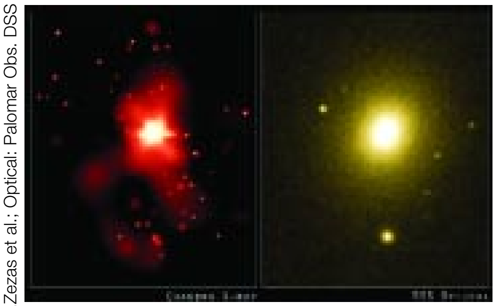
Goal 5
Explore the solar system and the universe beyond, understand the origin and evolution of life, and search for evidence of life elsewhere.

OBJECTIVE 5.11

Learn what happens to space, time, and matter at the edge of a black hole.

WHY PURSUE OBJECTIVE 5.11?

The greatest extremes of gravity in the universe today exist at the edges of black holes. Matter captured by their strong gravity falls inward, accelerating to speeds close to that of light. This infalling gas, including gas from stars shredded by the intense gravity fields, heats up dramatically and produces large quantities of X-ray radiation near the edge of a black hole. Beyond the edge, time comes to a standstill, and matter disappears from view forever.



Credit: Chandra image: NASACXC/A.Zezas et al.; Optical: Palomar Obs. DSS

Figure 104: The Chandra X-ray Observatory image (left, released on December 8, 2003) of the elliptical galaxy NGC 4261 reveals dozens of black holes and neutron stars strung out across tens of thousands of light years like beads on a necklace. The spectacular structure, which is not apparent from the optical image of the galaxy on the right, is thought to be the remains of a collision between galaxies a few billion years ago. According to this interpretation, a smaller galaxy was captured and pulled apart by the gravitational tidal forces of NGC 4261. As the doomed galaxy fell into the larger galaxy, large streams of gas were pulled out into long tidal tails. Shock waves in these tidal tails triggered the formation of many massive stars. Over the course of a few million years, these stars evolved into neutron stars or black holes.

By measuring the X-rays at a black hole's edge, scientists can observe the slowing of time near the surface, as Einstein predicted, and investigate how infalling matter releases energy there. Scientists also can observe the evolution of black holes and quasars to determine their role in the evolution of their host galaxies.

Closer to home, NASA is using Gravity Probe B, launched in April 2004, to test Einstein's theory of space and time. Gravity Probe-B is a polar-orbiting satellite that will measure the remarkable effects caused by the distortion of space–time created by the spinning mass of Earth as predicted by Einstein's General Theory of Relativity.

NASA'S PROGRESS AND ACHIEVEMENTS IN FY 2004

The Space Science Advisory Committee, an external advisory board, reviewed the progress of Outcomes 5.11.1 through 5.11.3 and determined that NASA successfully demonstrated progress in all three Outcomes during FY 2004.

Outcome 5.11.1: Determine how black holes are formed, where they are, and how they evolve.

NASA made progress in this Outcome by coordinating observations from three different space telescopes to get a better look at black holes, understanding a new class of black holes, and determining how super-massive black holes are produced. As part of the Great Observatories Origins Deep Survey, NASA researchers used observations from the Spitzer Space Telescope, the Hubble Space Telescope, and the Chandra X-ray Observatory to demonstrate that 100 percent of approximately 200 X-ray sources believed to be super-massive black holes are located within young galaxies. Spitzer showed that previously unseen galaxies actually exist outside of Hubble's wavelength range. This result demonstrates the value of coordinating observations from NASA's three Great Observatories.

NASA researchers used Chandra to detect an "intermediate mass" black hole, i.e., one with approximately 1000 solar masses in a stellar cluster, in the starburst galaxy M82. Researchers used this stellar cluster as a model to calculate how the region produced this type of black hole, and these calculations explain the processes and conditions necessary to produce this new class of intermediate black holes. Meanwhile, recent calculations funded by the Astrophysics Theory Program suggest that super-massive black holes are produced by accretion of gas and not by mergers of smaller-mass black holes. When black holes merge, their final decay is fueled by energy loss due to gravitational radiation that also creates a momentum kick. In the earlier universe, galaxies were smaller, so black hole mergers likely ejected the black holes from their parent galaxies. Estimates of this kick led to this intriguing conclusion that might well be confirmed by future observations of off-center black holes that have recently received such a kick.

Outcome 5.11.2: Test Einstein's theory of gravity and map space-time near event horizons of black holes.

NASA continued testing Einstein's theory of gravity and mapping space-time near event horizons of black holes by launching Gravity Probe B, confirming Einstein's principle of the constant speed of light, and observing a spinning black hole. NASA successfully launched Gravity Probe B on April 20, 2004. Over the next year, the probe will test two predictions of Einstein's General Theory of Relativity to unprecedented precision. NASA scientists also confirmed that Albert Einstein's principle of the constancy of the speed of light (i.e., the speed of light is constant, even at extremely high energies) holds up under extremely tight scrutiny. This new research rules out some current theories predicting extra dimensions and a "frothy" fabric of space. Researchers also used Chandra and XMM-Newton to study two stellar black holes, Cygnus X-1 and XTE J1650-500. The X-ray observations revealed that the latter black hole has a high spin rate. The presence of a lower tail implies X-ray origin at 20 km from the black hole horizon, compared to a minimum X-ray origin of 100 km from the horizon of the Cygnus X-1 black hole. This demonstrates that the geometry of a spinning black hole allows atoms to orbit closer to the black hole than for a non-spinning black hole.

Credit: Stanford University

Figure 105: The Gravity Probe B spacecraft launches from Vandenberg Air Force Base on April 20, 2004.

Outcome 5.11.3: Observe stars and other material plunging into black holes.

NASA researchers used X-ray data from XMM-Newton and Chandra to provide direct evidence of the catastrophic destruction of a star that wandered too close to a super-massive black hole. The observations confirmed that a powerful X-ray outburst had occurred in the center of the galaxy RX J1242-11, which appears normal in a ground-based optical image. This X-ray outburst, one of the most powerful ever detected in a galaxy, was caused when gas from the disrupted star was heated to multi-million degree temperatures as it fell toward the black hole.

Performance Measures for Objective 5.11		2004 Rating	Past Years' Performance Measures and Ratings	2003	2002	2001
Outcome 5.11.1	Determine how black holes are formed, where they are, and how they evolve.	green		Outcomes originated in FY 2004		
APG 4SEU12	Successfully demonstrate progress in determining how black holes are formed, where they are, and how they evolve. Progress towards achieving outcomes will be validated by external review.	green		none	none	none
Outcome 5.11.2	Test Einstein's theory of gravity and map space-time near event horizons of black holes.	green		Outcomes originated in FY 2004		
APG 4SEU13	Successfully demonstrate progress in testing Einstein's theory of gravity and mapping space-time near event horizons of black holes. Progress towards achieving outcomes will be validated by external review.	green		3S2 green	2S2 green	none
Outcome 5.11.3	Observe stars and other material plunging into black holes.	green		Outcomes originated in FY 2004		
APG 4SEU14	Successfully demonstrate progress in observing stars and other material plunging into black holes. Progress towards achieving outcomes will be validated by external review.	green		none	none	none

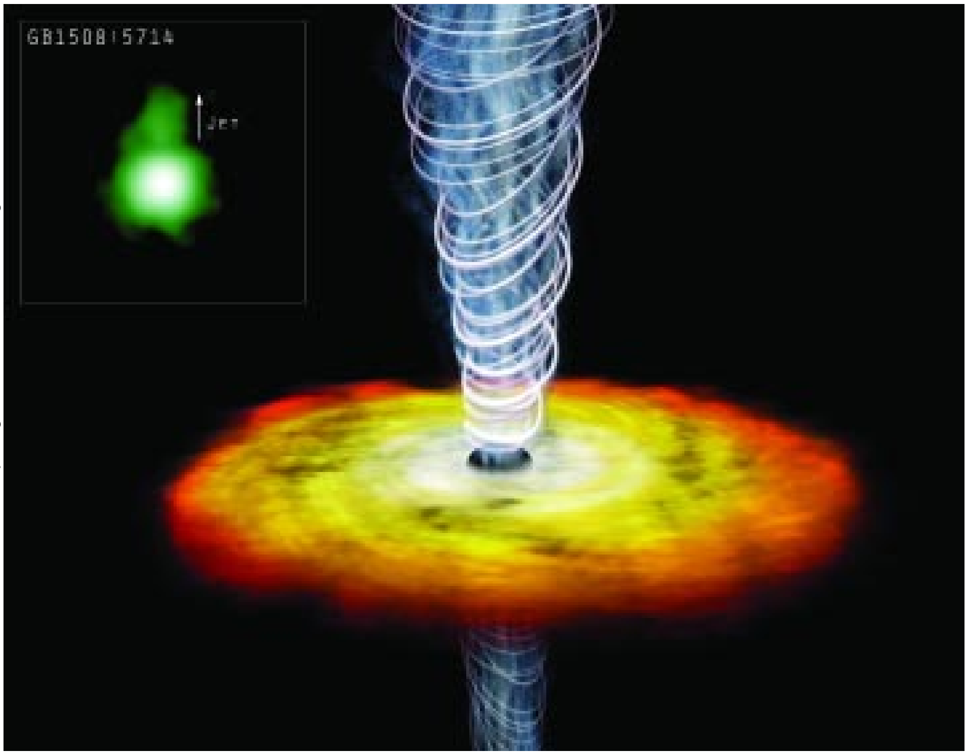
Goal 5
Explore the solar system and the universe beyond, understand the origin and evolution of life, and search for evidence of life elsewhere.

OBJECTIVE 5.12

Understand the development of structure and the cycles of matter and energy in the evolving Universe.

WHY PURSUE OBJECTIVE 5.12?

The universe is governed by cycles of matter and energy. Even as the universe expands, pockets of atomic matter and dark matter collapse by the force of gravity to form galaxies and clusters of galaxies. Dense clouds of gas within the galaxies collapse to form stars, and in the star centers, all elements heavier than hydrogen and helium are produced. When stars die, they eject some of these freshly produced, heavier elements into space forming galactic clouds of gas and dust in which future generations of stars are born, beginning another cycle of matter.



Credit: Illustration: CXC/M.Weiss; X-ray image: NASA/CXC/SAO/A.Siemiginowska et al.

Figure 106: This drawing of a Chandra X-ray Observatory image of the quasar GB1508+5714 reveals a jet of high-energy particles that extends more than 100,000 light years from the supermassive black hole powering the quasar. At a distance of 12 billion light years from Earth, this is the most distant jet ever detected. The discovery of this jet is especially significant because it provides astronomers with a way to measure the intensity of the cosmic background radiation about one billion years after the Big Bang. The jet's brightness implies that enormous amounts of energy were deposited in the outer regions of the host galaxy of the quasar at a very early stage. This energy input could have had a profound effect on the evolution of the galaxy by triggering the formation of stars, or inhibiting the accretion of matter from intergalactic space.

The luminous energy of stars comes from thermonuclear fusion: hydrogen and helium gas are burned, leaving as "ash" the heavier elements. When a star's fuel is consumed, its life ends, releasing vast quantities of energy. This energy strongly affects the environment of nearby stars and is believed to be responsible for cosmic rays, atomic particles moving at nearly the speed of light that constantly bombard Earth.

NASA is studying the cycles of matter and energy and how they created the conditions that spawned life. To understand how matter and energy are exchanged between stars and the interstellar medium, NASA is studying winds, jets, and explosive events. To understand the formation of galaxies, NASA is mapping the "invisible" universe of dark matter that helped nucleate these structures, observing the gas expelled during the birth of galaxies, and witnessing the birth of the first black holes and their effect on the formation of galaxies.

NASA'S PROGRESS AND ACHIEVEMENTS IN FY 2004

The Space Science Advisory Committee, an external advisory board, reviewed the progress of Outcomes 5.12.1 through 5.12.3 and determined that NASA successfully demonstrated progress in all three Outcomes during FY 2004.

Outcome 5.12.1: Determine how, where, and when the chemical elements were made, and trace the flows of energy and magnetic fields that exchange them between stars, dust, and gas.

NASA researchers, using Chandra, discovered rich abundances of neon, magnesium, and silicon in the Antennae, a pair of colliding galaxies. The collision of gas clouds in these galaxies resulted in a high rate of massive star formation and supernovae and heavy element enrichment from the ejection. Researchers now know this likely means that there will be a much higher density of planets in next-generation stellar systems, increasing the probability of formation of life in the region of activity.

The Galaxy Evolution Explorer completed the first year of its first extra-galactic, ultraviolet, all-sky survey. During its 29-month mission, the Galaxy Evolution Explorer will produce the first comprehensive map of a universe of galaxies under construction.

The Hubble Space Telescope took a one-million-second long exposure that may have revealed the first galaxies to emerge from the "dark ages," the period before stars started to form, about 13 billion years ago.

Outcome 5.12.2: Explore the behavior of matter in extreme astrophysical environments, including disks, cosmic jets, and the sources of gamma-ray bursts and cosmic rays.

NASA made progress toward this Outcome thanks to observations from the Roentgen X-ray Timing Explorer, XMM-Newton, and the Chandra X-ray observatory. Researchers using the Roentgen X-ray Timing Explorer observed a "superburst" on a neutron star that is providing valuable new clues about the innermost region of the hot accretion disk surrounding the neutron star. This is the first time that a disk near the innermost stable orbit has been seen changing its structure in real time in response to irradiation from neutron star bursts. The XMM-Newton observed in X-rays a spectacular set of expanding rings, energized by a powerful gamma-ray burst that took place in December 2003. Due to the effects of special relativity, these rings appeared to expand at a speed 1000 times greater that that of light. This fascinating event is called an "echo," and it had not been seen previously in X-rays.

Chandra observed the presence of large amounts of iron and nickel in a jet-like structure associated with the supernova remnant W49B. This suggests that the massive original star did not end its life as a normal core-collapse supernova. Instead, it is possible that the star ended as a gamma-ray burst, spewing its iron nuclei out through its jets. Images from the Palomar Observatory showed that the explosion took place in a dense molecule cloud implying a short lifetime and a large mass since the star exploded so close to where it was formed. This data is consistent with the "collapsar" model of gamma-ray bursts; if confirmed, this would be the first galactic gamma-ray burst remnant detected. The presence of a gamma-ray burst within this galaxy, coupled with the young age of the supernova remnant, could help pinpoint the rate of gamma-ray bursts.

Outcome 5.12.3: Discover how the interplay of baryons, dark matter, and gravity shapes galaxies and systems of galaxies.

Observations from the Hubble Space Telescope, the Chandra X-ray Observatory, and XMM-Newton helped researchers determine that the galaxy cluster RCDS1252.9-292 was fully formed more than 8 billion years ago and has a mass at least 300 trillion times that of the Sun. At a distance of 8.6 billion light years, it is the most massive cluster ever observed at such an early stage in the evolution of the universe. Even though the cluster appears as it did only five billion years after the Big Bang, it has an abundance of elements similar to that of clusters observed in more recent epochs. The cluster gas must have been enriched by heavy elements synthesized in stars and ultimately ejected from the galaxies. The observations of RDCS1252 are consistent with the theory that massive stars produced most of these heavy elements more than 11 billion years ago.

Observations made with Chandra also may explain why so little cool gas is found within galaxy clusters. Chandra captured sound waves generated by a super-massive black hole in the Perseus galaxy cluster. Cooling by x-ray emission of the hot gas within galaxy clusters should result in substantial star formation, but this was not seen. In fact, the lack of star formation implies the presence of a heating mechanism, a possibility unknown until now. Researchers now believe that the presence of "black hole acoustics" likely supplies this energy and transports the equivalent energy of 100 million supernovae over distances of hundreds of thousands of light years.

Researchers using XMM-Newton observations of two quasars (PDS 456 and PG 1211+143) revealed that the presence of high velocity ionized outflows suggests that quasars may be injecting very large energies into the interstellar or intergalactic medium. The Chandra team also took long-exposure images of the giant elliptical galaxy M87 that revealed repetitive outbursts from the vicinity of the super-massive black hole. Features detected include jets, magnetized bubbles formed by their collision with surrounding gas, and sound waves emanating from the bubbles. The episodic outbursts are explained as a self-regulated, cyclic system: Cool gas flows into the vicinity of the black hole, creating activity that heats the surrounding gas. This inhibits the gas inflow, shutting down the black hole activity.

Performance Measures for Objective 5.12		2004 Rating	Past Years' Performance Measures and Ratings	2003	2002	2001
Outcome 5.12.1	Determine how, where, and when the chemical elements were made, and trace the flows of energy and magnetic fields that exchange them between stars, dust, and gas.	green		Outcomes originated in FY 2004		
APG 4SEU15	Successfully demonstrate progress in determining how, where, and when the chemical elements were made, and tracing the flows of energy and magnetic fields that exchange them between stars, dust, and gas. Progress towards achieving outcomes will be validated by external review.	green		none	none	none
Outcome 5.12.2	Explore the behavior of matter in extreme astrophysical environments, including disks, cosmic jets, and the sources of gamma-ray bursts and cosmic rays.	green		Outcomes originated in FY 2004		
APG 4SEU16	Successfully demonstrate progress in exploring the behavior of matter in extreme astrophysical environments, including disks, cosmic jets, and the sources of gamma-ray bursts and cosmic rays. Progress towards achieving outcomes will be validated by external review.	green		3S2 green	2S2 green	none
Outcome 5.12.3	Discover how the interplay of baryons, dark matter, and gravity shapes galaxies and systems of galaxies.	green		Outcomes originated in FY 2004		
APG 4SEU17	Successfully demonstrate progress in discovering how the interplay of baryons, dark matter, and gravity shapes galaxies and systems of galaxies. Progress towards achieving outcomes will be validated by external review.	green		3S1 blue	2S1 green	none

Goal 5 Explore the solar system and the universe beyond, understand the origin and evolution of life, and search for evidence of life elsewhere.

OBJECTIVE 5.13

Through robotic and human lunar missions, demonstrate capabilities, including use of lunar and other space resources, for safe, affordable, effective and sustainable human-robotic solar system exploration.

WHY PURSUE OBJECTIVE 5.13?

On December 13, 1972, Apollo 17 astronaut Eugene Cernan concluded the last human activities on the Moon with the statement, "I believe history will record that America's challenge of today has forged man's destiny of tomorrow." The next morning, the lander left the lunar surface to rejoin the orbiting command module and return home. More than 20 years later, in 2004, NASA announced that the Agency would meet that destiny and return humans to the Moon.

Figure 107: The Lunar Prospector, shown in an artist's concept, was NASA's last lunar mission. Launched in January 1998, this robotic mission mapped the surface composition of the Moon and searched for resources, such as the significant amounts of water ice it found at the lunar poles. With The Vision for Space Exploration, NASA announced its goal of returning both automated spacecraft and humans to the Moon.

Built on testbed activities aboard the International Space Station, NASA is developing technologies that will make advanced lunar exploration possible. The next phase of lunar exploration will involve a series of robotic missions, both orbiters and landers, to confirm and map lunar resources in detail. NASA also is planning missions to demonstrate new technological capabilities including robotic networks, reusable planetary landing and launch systems, prepositioned propellants that can serve as refueling depots, and resource extraction. The final phase will be to return human explorers to the Moon where they will demonstrate human exploration capabilities—resource utilization, habitation and life support, and planetary mobility—within relatively safe reach of Earth. These missions will be humankind's first steps toward exploring Mars and destinations beyond.

NASA'S PROGRESS AND ACHIEVEMENTS IN FY 2004

In January 2004, NASA embraced the President's goal of returning humans to the Moon as a stepping-stone to human exploration of Mars and beyond. NASA is in the process of crafting a lunar program. Therefore, the Outcomes in this objective reflect NASA's future plans. In addition, since NASA's lunar program plan is in its infancy, the achievements under Outcome 5.13.1 also apply to Outcomes 5.13.2 through 5.13.4.

Outcome 5.13.1: Develop capability to conduct robotic lunar test bed missions by 2008 and human lunar missions as early as 2015 but no later than 2020 that can demonstrate exploration systems and architectural approaches, including use of lunar resources, to enable human-robotic exploration across the solar system.

To support near-term robotic missions to the Moon and future human exploration of the Moon and Mars, NASA established the Robotic Lunar Exploration Program Office under the leadership of a Director and a Lead Scientist, within the Solar System Exploration Division of NASA's Science Mission Directorate. In addition, the Science Mission Directorate assigned responsibility for implementation of the robotic lunar exploration program to the Goddard Space Flight Center under the guidance of a Lunar Program Manager.

The first robotic mission to prepare for future human exploration is the 2008 Lunar Reconnaissance Orbiter mission. The Orbiter will conduct investigations from lunar orbit that will be targeted specifically at preparing NASA to support future human exploration of the Moon. A science community-based Objectives and Development Team, in coordination with other related offices within NASA, developed and approved requirements for the Orbiter in March 2004. NASA released the competitive Announcement of Opportunity for the Orbiter's instrument payload on June 18. The Agency also initiated activities that will ensure broad community involvement in long-term robotic lunar exploration planning beyond 2008 (e.g., science priority recommendations, mission trade studies, and investigation pathways). As part of the larger effort to implement NASA's Vision for Space Exploration, NASA's Exploration Systems Mission Directorate also identified, catalogued, and evaluated pertinent past lunar exploration architecture concepts and trade studies necessary for formulating options and requirements for future human-robotic exploration.

Outcome 5.13.2: Conduct robotic missions, in lunar orbit and on the lunar surface, to acquire engineering and environmental data by 2015 required to prepare for human-robotic lunar missions.

See discussion under Outcome 5.13.1.

Outcome 5.13.3: By 2020, establish through lunar surface missions the building block capabilities to support safe, affordable and effective long-duration human presence beyond low Earth orbit (LEO) as a steppingstone to sustained human-robotic exploration and discovery beyond the Moon.

See discussion under Outcome 5.13.1.

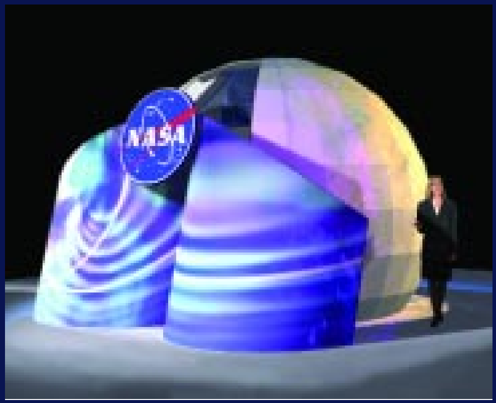
Outcome 5.13.4: By 2015, demonstrate new human-robotic space operations capabilities employing advanced in-space infrastructures, including space assembly, maintenance and servicing, and logistics concepts.

See discussion under Outcome 5.13.1.

Performance Measures for Objective 5.13		2004 Rating	Past Years' Performance Measures and Ratings	2003	2002	2001
Outcome 5.13.1	Develop capability to conduct robotic lunar test bed missions by 2008 and human lunar missions as early as 2015 but no later than 2020 that can demonstrate exploration systems and architectural approaches, including use of lunar resources, to enable human–robotic exploration across the solar system.	green		Outcomes originated in FY 2004		
APG 4LE1	Identify and analyze past architecture-definition and trade studies with applicability to lunar human–robotic exploration tests.	green		none	none	none
Outcome 5.13.2	Conduct robotic missions, in lunar orbit and on the lunar surface, to acquire engineering and environmental data by 2015 required to prepare for human–robotic lunar missions.	green		Outcomes originated in FY 2004		
Outcome 5.13.3	By 2020, establish through lunar surface missions the building block capabilities to support safe, affordable and effective long-duration human presence beyond low Earth orbit (LEO) as a steppingstone to sustained human–robotic exploration and discovery beyond the Moon.	green		Outcomes originated in FY 2005		
Outcome 5.13.4	By 2015, demonstrate new human–robotic space operations capabilities employing advanced in-space infrastructures, including space assembly, maintenance and servicing, and logistics concepts.	green		Outcomes originated in FY 2006		

Mission: To Inspire the Next Generation of Explorers

Goal 6: Inspire and motivate students to pursue careers in science, technology, engineering, and mathematics.



Goal 7: Engage the public in shaping and sharing the experience of exploration and discovery.

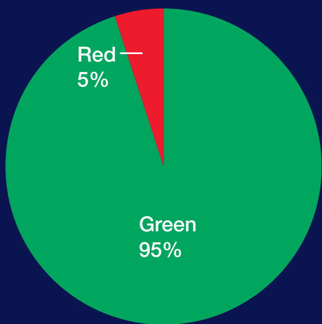
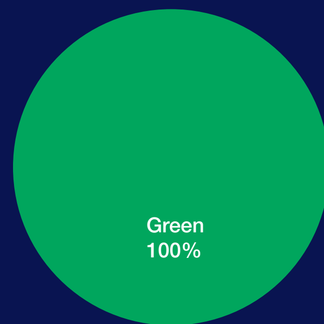


Figure 108: NASA achieved 95 percent of the APGs in Goal 6.



NASA is on track to achieve 100 percent of its Outcomes under Goal 6.

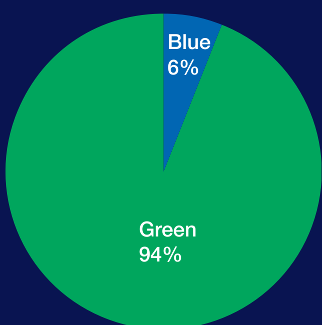
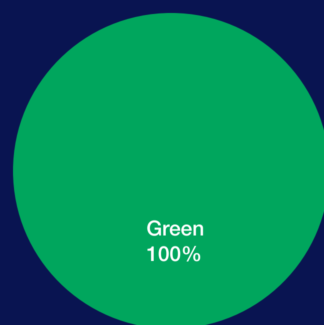


Figure 109: NASA achieved 100 percent of the APGs in Goal 7.



NASA is on track to achieve 100 percent of its Outcomes under Goal 7.

APG color ratings:

- Blue: Significantly exceeded APG
- Green: Achieved APG
- Yellow: Failed to achieve APG, progress was significant, and achievement is anticipated within the next fiscal year.
- Red: Failed to achieve APG, do not anticipate completion within the next fiscal year.
- White: APG was postponed or cancelled by management directive.

Outcome color ratings:

- Blue: Significantly exceeded all APGs. On track to exceed this Outcome as stated.
- Green: Achieved most APGs. On track to fully achieve this Outcome as stated.
- Yellow: Progress toward this Outcome was significant. However, this Outcome may not be achieved as stated.
- Red: Failed to achieve most APGs. Do not expect to achieve this Outcome as stated.
- White: This outcome as stated was postponed or cancelled by management directive or the Outcome is no longer applicable as stated based on management changes to the APGs.

Goal 6
Inspire and motivate students to pursue careers in science, technology, engineering, and mathematics.

OBJECTIVE 6.1

Increase the number of elementary and secondary students and teachers who are involved in NASA-related education opportunities.

WHY PURSUE OBJECTIVE 6.1?

To inspire the next generation of scientists, technologists, engineers, and educators, NASA cannot rely on the past. The Agency has to engage the education community and invite them to participate in ongoing work and the process of discovery. With its ability to capture the imagination of educators, students, and the general public, NASA has a unique capacity to help revitalize science, technology, engineering, and mathematics (STEM) education in America.

Figure 110: NASA-sponsored education programs demonstrate the relationship between NASA's research and textbook learning. Here, students measure and record plant height for a graphing exercise using *Brassica rapa* plants, a member of the mustard plant family that has been used for research on the Shuttle, the Russian space station *Mir*, and the International Space Station.

When students are inspired, they are motivated to learn more and assume more difficult challenges, such as those posed in the study of higher levels of STEM. To continue challenging these students, educators must have the tools, experiences, and opportunities to further their own education in STEM areas. NASA provides scientific content, advanced technological tools, and supplemental educational services as part of an educational pipeline that extends from elementary through secondary education and beyond. NASA partners with external agencies and organizations, including national, state, and local education associations, to meet the needs of America's educational community at all levels.

NASA'S PROGRESS AND ACHIEVEMENTS IN FY 2004

Outcome 6.1.1: By 2008, increase by 20%, student participation in NASA instructional and enrichment activities.

In FY 2004, NASA implemented the Educator Astronaut Program and the NASA Explorer Schools Program. Student participation increased by 100 percent for both programs. Through these programs, students participate in a rich array of individual and group-learning activities.

The Educator Astronaut Program directs talented and diverse students and researchers into targeted opportunities and experiences leading to NASA-related career possibilities and decisions. This fiscal year, NASA registered 122,899 people as Earth Crew members, the ground-based component of the Educator Astronaut Program. Approximately 87,000 of these Earth Crew members are students. NASA also trained 181 teachers in the Network of Educator Astronaut Teachers who will interact with approximately 9,000 teachers this year to give them NASA content and teaching strategies for their classrooms.

The Agency also doubled the number of schools in the NASA Explorer School Program. One hundred schools now participate, and an additional 50 schools are anticipated to participate during FY 2005. The Explorer Schools Program currently reaches 70,000 students.

In FY 2004, NASA also achieved the following:

- NASA's Science, Engineering, Mathematics, and Aerospace Academy served 17,148 students in 796 primary and secondary schools in 57 counties across the continental United States, resulting in a 37 percent increase.

Figure 111: The three educator astronaut candidates from the 2004 astronaut class participate in an Earth Crew Webcast on May 6, 2004: (from left) Dorothy (Dottie) Metcalf-Lindenburger, Richard (Ricky) Arnold II, and Joseph (Joe) Acaba.

- Twenty-seven thousand participants joined in STEM-related activities nationwide as part of NASA's Saturday Academy Programs.
- NASA's Science, Engineering, Communication, Mathematics Enhancement Program reached 39,326 students in FY 2004. Participating students average overall Scholastic Aptitude Test scores of 1155 versus the national average of 946.
- The Summer High School Apprenticeship Research Program placed 382 summer student interns at NASA's Centers and partner universities.

Outcome 6.1.2: By 2008, increase by 20%, the number of elementary and secondary educators effectively utilizing NASA content-based STEM materials and programs in the classroom.

The NASA Explorer Schools Program increased the number of competitively selected participating schools to 100. Educators in these schools participate in a variety of individualized professional development activities where they are introduced to NASA materials ranging from lesson guides to interactive multimedia programs. NASA currently is conducting an independent evaluation of the program to determine the degree to which the resources are used effectively. NASA also achieved the following:

- The Educator Astronaut Programs' Network of Educator Astronaut Teachers Activity continued to give participants an opportunity to utilize NASA materials and participate in curriculum development.
- The Edspace Web site (http://edspace.nasa.gov) continued to provide content based on astronaut training for educators to use in the classroom.
- The Science, Engineering, Communication, Mathematics Enhancement Program hosted several workshops for educators. In FY 2004, 8,412 teachers in the program used NASA content-based STEM materials.

Outcome 6.1.3: By 2008, increase by 20%, family involvement in NASA-sponsored elementary and secondary education programs.

NASA made progress in incorporating family involvement into selected activities primarily through the Science, Engineering, and Mathematics Aerospace Academy. The Academy involves families through the Family Café, an interactive forum that provides educational and parenting information to adult caregivers and other supportive adults who are involved actively in the student's life. The Family Café also puts these adults in touch with various local resources and programs that are available for the student. Beginning in FY 2005, family involvement also will become a part of every NASA Explorer School visit by NASA education specialists. Other activities include the following:

Figure 112: NASA provides educators with professional development activities and materials that help them bring the excitement of space to the classroom.

- NASA Centers invited family members and the community to attend the opening and closing ceremonies for NASA's Summer High School Apprenticeship Research Program.
- NASA's Science, Engineering, Communication, Mathematics Enhancement Program includes a family component in its programs. In FY 2004, 27,483 parents participated in the related Empowering Parents to Excel at Parenting program. In an annual program performance evaluation, chartered by the Office of Education and using standard criteria, Excel at Parenting received an overall rating of 4.45 out of a possible 5.0.

Outcome 6.1.4: By 2008, 90% of NASA elementary and secondary programs are aligned with state or local STEM educational objectives.

NASA education program managers involve local educators in program planning to ensure alignment with state and local education standards. Some programs, like the NASA Explorer Schools, require a needs assessment to assist in the determination and matching of appropriate NASA materials and programs that will be provided through professional development. Currently, NASA keeps education information on every state and Puerto Rico, Guam, and the Virgin Islands in the NASA State Directory which is accessible via the NASA Portal (www.nasa.gov). All Aerospace Education Services Program specialists receive state-based training and are knowledgeable in the frameworks of their assigned states. A peer-review assessment of the alignment will be conducted in the near future.

Performance Measures for Objective 6.1		2004 Rating	Past Years' Performance Measures and Ratings	2003	2002	2001
Outcome 6.1.1	By 2008, increase by 20%, student participation in NASA instructional and enrichment activities.	green		Outcomes originated in FY 2004		
APG 4ED1	Develop protocols to establish a baseline of NASA student participation.	green		none	none	none
APG 4ED2	Develop and implement at least one model program, based on best practices, that engages students in NASA science and technology (inclusive of the science and technical Enterprises).	green		none	none	none
Outcome 6.1.2	By 2008, increase by 20% the number of elementary and secondary educators effectively utilizing NASA content-based STEM materials and programs in the classroom.	green		Outcomes originated in FY 2004		
APG 4ED3	Develop protocols to establish a baseline of NASA teacher participation.	green		none	none	none
APG 4ED4	Develop and implement a model program, based on best practices, that engages teachers in NASA science and technology (inclusive of the science and technical Enterprises).	green		none	none	none
Outcome 6.1.3	By 2008, increase by 20% family involvement in NASA-sponsored elementary and secondary education programs.	green		Outcomes originated in FY 2004		
APG 4ED5	Establish a baseline of existing NASA sponsored family involvement activities and existing and potential partners.	green		none	none	none
APG 4ED6	Using an established best-practices model, implement one NASA-sponsored family involvement component/program at each Center.	green		none	none	none
Outcome 6.1.4	By 2008, 90% of NASA elementary and secondary programs are aligned with state or local STEM educational objectives.	green		Outcomes originated in FY 2004		
APG 4ED7	Establish a baseline to determine the number of states in which NASA state-based programs are being implemented.	green		none	none	none

Goal 6 Inspire and motivate students to pursue careers in science, technology, engineering, and mathematics.

OBJECTIVE 6.2

Support higher education research capability and opportunities that attract and prepare increasing numbers of students and faculty for NASA-related careers.

WHY PURSUE OBJECTIVE 6.2?

The NASA Mission—to understand, explore, and inspire—depends on people with the ingenuity to invent new tools, the passion to solve problems, and the courage to ask difficult questions. However, recent data indicates a decline in the number of students pursuing degrees in the disciplines of science, technology, engineering, and mathematics. Combined with a shortage of mathematics, science, and technology teachers, an aging aerospace workforce, and employee recruitment competition, the future of U.S. advancements in science, aeronautics, and aerospace is at risk.

Figure 113: The NASA workforce of tomorrow is being trained today in our institutions of higher education.

NASA is strengthening involvement with higher education institutions to meet the Agency's future workforce needs by encouraging more students to continue their studies and earn advanced degrees in these critical fields. NASA is improving coordination between NASA-sponsored university research activities and teacher preparation programs to expose teachers-in-training to NASA research and discoveries. Through faculty development opportunities, NASA also is increasing the candidate pool of qualified faculty and institutions that can compete for NASA research awards. NASA has an inspiring mission of exploration and discovery and world-class laboratories and facilities. The Agency provides students, teachers, and professionals access to this wealth of information and capabilities through scholarship programs, research grants, and other opportunities—bringing these future scientists, engineers, and mathematicians into the NASA family.

NASA'S PROGRESS AND ACHIEVEMENTS IN FY 2004

Outcome 6.2.1: By 2008, attain a statistically significant increase in the number and diversity of NASA-supported students graduating in NASA-related fields.

In FY 2004, NASA developed a baseline of the number of students supported by the Agency. NASA also collected demographic data to measure diversity. The Science and Technology Scholarship Program will be fully implemented in FY 2005 and will add to the base of NASA-supported students.

Outcome 6.2.2: By 2008, attain a statistically significant increase in the number of faculty in higher education institutions who are first-time proposers in NASA research and development opportunities.

NASA's programs for faculty are designed to involve new faculty in NASA research, especially those at historically underserved, underrepresented universities and colleges. Currently, substantial anecdotal evidence indicates that NASA is helping faculty members develop and submit high-quality proposals for the first time and is on track to achieve this Outcome. NASA also has added new data elements to track the number of faculty who propose for the first time. By implementing a tracking system to collect this data, the Agency will be able to document performance on this Outcome.

Outcome 6.2.3: By 2008, increase by 20% the number of higher education institutions that align their NASA research and development activities with STEM teacher preparation departments to improve STEM teacher quality.

NASA made progress toward increasing the number of higher education programs that align NASA activities with STEM teacher preparation through two pre-service education programs. The first, NASA's Project NOVA, is a national pre-service activity that collaborates with science, engineering, and education departments to prepare the next generation of teachers. Faculty at NOVA institutions represent both science and education departments involved in teacher preparation. Ninety-two institutions in 34 states and more than 750 university faculty members have participated in the program. NOVA has reached more than 40,000 university students and participating universities and colleges have created more than 150 new/modified courses.

Figure 114: NASA provides undergraduate and graduate students with the opportunity to fly experiments on the KC-135, shown here, and is looking to increase opportunities to fly experiments on the International Space Station.

The second program, the NASA Langley Pre-Service Teacher Program, is a partnership with Norfolk State University's School of Science and Technology. The program provides pre-service teachers and faculty members with opportunities to enhance their knowledge and skill in teaching mathematics and science using technology at the elementary and middle school levels. The FY 2004 Pre-Service Teacher Conference hosted approximately 700 prospective teachers from selected Historically Black Colleges and Universities, Hispanic Serving Institutions, Tribal Colleges and Universities, and some majority institutions.

Outcome 6.2.4: By 2008, increase by 10% the number and diversity of students conducting NASA-relevant research.

NASA initiated several activities in FY 2004 to engage students in NASA research. Currently, programs like the Undergraduate Student Research Program and its companion, the Graduate Student Research Program, engage students in research at NASA Centers. NASA also is creating a Flight Projects Office to help in this effort. This office will facilitate research opportunities for students using flight platforms like the International Space Station. Students also are proposing and flying experiments on NASA's KC-135, a plane that flies a special flight pattern to simulate periods of weightlessness. NASA continues to develop the infrastructure, staffing, and opportunities necessary to support these activities.

Performance Measures for Objective 6.2		2004 Rating	Past Years' Performance Measures and Ratings	2003	2002	2001
Outcome 6.2.1	By 2008, attain a statistically significant increase in the number and diversity of NASA-supported students graduating in NASA-related fields.	green		Outcomes originated in FY 2004		
APG 4ED8	Establish a NASA-wide baseline of the number and diversity of NASA-supported students.	green		none	none	none
Outcome 6.2.2	By 2008, attain a statistically significant increase in the number of faculty in higher education institutions who are first-time proposers in NASA research and development opportunities.	green		Outcomes originated in FY 2004		
APG 4ED9	Develop an inventory identifying the number of first-time proposers and the universe of faculty in higher education institutions involved with NASA research and development opportunities.	red		none	none	none
Outcome 6.2.3	By 2008, increase by 20% the number of higher education institutions that align their NASA research and development activities with STEM teacher preparation departments to improve STEM teacher quality.	green		Outcomes originated in FY 2004		
APG 4ED10	Develop a model to demonstrate how NASA's investment in higher education institutions can influence the quality of pre-service education in STEM fields.	green		none	none	none
Outcome 6.2.4	By 2008, increase by 10% the number and diversity of students conducting NASA-relevant research.	green		Outcomes originated in FY 2004		
APG 4ED11	Develop an infrastructure and funding plan that provides Education sponsored flight research opportunities (including STS, ISS, ELV, balloons, and sounding rockets) for graduate, undergraduate, and selected high school students.	green		none	none	none

Note: See NASA's Performance Improvement Plan at the end of Part 2 for details on FY 2004 APGs and Outcomes rated Red, Yellow, or White.

Goal 6 Inspire and motivate students to pursue careers in science, technology, engineering, and mathematics.

OBJECTIVE 6.3

Increase the number and diversity of students, teachers, faculty and researchers from underrepresented and underserved communities in NASA related STEM fields.

WHY PURSUE OBJECTIVE 6.3?

Increasing the number of students that become inspired to study and enter into science, technology, engineering, and mathematics (STEM), as well as teaching career fields, requires NASA to expand its existing educational opportunities and create new opportunities. NASA strives to reach underrepresented and underserved students and to encourage more of these students to pursue STEM careers. To help achieve this, NASA recognizes the role of teachers, faculty, and families in developing successful students. NASA continues to focus on enhancing the capabilities of Historically Black Colleges and Universities, Hispanic Serving Institutions, and Tribal Colleges and Universities to contribute to the Agency's research needs. NASA also encourages these institutions to collaborate with teacher preparation programs to improve the quality and diversity of STEM teachers. National, state, and local associations, organizations, and institutions knowledgeable about the needs and capabilities of underrepresented and underserved populations guide NASA's program development and implementation.

Figure 115: NASA provides educational opportunities and tools that encourage students to study science, technology, engineering, and mathematics.

NASA'S PROGRESS AND ACHIEVEMENTS IN FY 2004

Outcome 6.3.1: By 2008, increase by 20%, underrepresented/underserved NASA-sponsored students who pursue academic degrees in NASA-related STEM disciplines.

NASA made progress toward increasing sponsorships of underrepresented/underserved students in STEM disciplines by including underserved students in the Agency's education program evaluation protocols. NASA used these protocols in program reviews and determined that the Agency is making good progress toward including a greater diversity of participants. NASA also developed a new scholarship program for underrepresented and underserved students to be implemented fully in FY 2005.

Outcome 6.3.2: By 2008, increase by 20%, the number and diversity of teachers and faculty from underrepresented/underserved communities and institutions who participate in NASA-related STEM programs.

NASA made progress toward increasing the number and diversity of underrepresented/underserved teachers participating in STEM programs by implementing an education portfolio assessment review process that emphasizes diversity. The assessment reflects good progress toward this Outcome.

Outcome 6.3.3: By 2008, increase by 20% the number of underrepresented/underserved researchers and minority serving institutions that compete for NASA research and development opportunities.

NASA made progress toward increasing the number of underrepresented/underserved researchers competing for NASA research and development opportunities by providing ten technical assistance workshops for minority institutions. NASA also protected minority university program funding from potential Agency budget reductions. These actions will ensure that minority researchers continue to be included in the NASA competition process. NASA also established a baseline for this Outcome, and the Agency is confident that the planned increases will occur.

Outcome 6.3.4: By 2008, increase family involvement in underrepresented/underserved NASA-sponsored student programs.

NASA made progress toward increasing family involvement through the Science, Engineering, and Mathematics Aerospace Academy. In addition to locating 13 of the Academy sites at minority institutions, the Academy involves families through the Family Café, an interactive forum that provides educational and parenting information to adult caregivers who are involved in the student's life. The Family Café model also was adopted by the Science, Engineering, Communication, and Mathematics Enhancement Program which serves underserved and underrepresented students.

Performance Measures for Objective 6.3		2004 Rating	Past Years' Performance Measures and Ratings	2003	2002	2001
Outcome 6.3.1	By 2008, increase by 20% underrepresented/underserved NASA-sponsored students who pursue academic degrees in NASA-related STEM disciplines.	green		Outcomes originated in FY 2004		
APG 4ED12	Develop protocols to establish a baseline of NASA underrepresented/underserved student participation.	green		none	none	none
APG 4ED13	Develop a model undergraduate program, based on best practices, bridging current programs, that engages underrepresented/underserved students.	green		none	none	none
Outcome 6.3.2	By 2008, increase by 20% the number and diversity of teachers and faculty from underrepresented/underserved communities and institutions who participate in NASA-related STEM programs.	green		Outcomes originated in FY 2004		
APG 4ED14	Develop protocols to establish a baseline of NASA underrepresented/underserved teacher/faculty participation in NASA STEM-related learning environments.	green		none	none	none
Outcome 6.3.3	By 2008, increase by 20% the number of underrepresented/underserved researchers and minority serving institutions that compete for NASA research and development opportunities.	green		Outcomes originated in FY 2004		
APG 4ED15	Establish a baseline of the numbers of underserved/underrepresented researchers and minority serving institutions competing for NASA research announcements.	green		none	none	none
APG 4ED16	Conduct 3 technical assistance workshops.	green		none	none	none
Outcome 6.3.4	By 2008, increase family involvement in underrepresented/underserved NASA-sponsored student programs.	green		Outcomes originated in FY 2004		
APG 4ED17	Using an established best-practices model, pilot a NASA-sponsored family involvement component in one underrepresented/underserved NASA-sponsored student program.	green		none	none	none

Goal 6
Inspire and motivate students to pursue careers in science, technology, engineering, and mathematics.

OBJECTIVE 6.4

Increase student, teacher, and public access to NASA education resources via the establishment of e-Education as a principal learning support system.

WHY PURSUE OBJECTIVE 6.4?

In the future, powerful technologies will enable new learning environments using simulations, visualizations, immersive environments, gameplaying, and learner networking. These capabilities will create rich and compelling learning opportunities that meet the needs of learners while empowering educators to unlock each student's potential. Learning will be on demand. Students and educators will receive what they need, when they need it—anytime, anywhere. NASA is working toward this education future, developing new methods for making its exciting discoveries and valuable resources available to students, educators, and teachers. The Agency is continually challenged to develop a delivery system that is timely and accurate while protecting the intellectual capital of research scientists. NASA is committed to finding the right balance in this challenge so that educators and students will continue to have access to NASA's engaging science content through digital media.

Figure 116: NASA uses the Web to give students and educators around the country easy access to a wide variety of unique activities and resources.

NASA'S PROGRESS AND ACHIEVEMENTS IN FY 2004

Outcome 6.4.1: By 2008, identify and implement 4 new advanced technology applications that will positively impact learning.

The NASA Learning Technologies Initiative creates teaching tools and applications to deliver NASA content in the most engaging and dynamic ways possible. An expert panel selected the current suite of four tools from an initial testbed of ten projects based on their feasibility and application to the classroom. The four projects are now in their second year of a three-year product development cycle, they include: the Johnson Space Center *Learning Technology Information Accessibility Lab*, the Kennedy Space Center *Learning Technology Virtual Lab*, the Ames Research Center *Learning Technology* "What's the Difference?" project, and the Goddard Space Flight Center *Animated Earth* project.

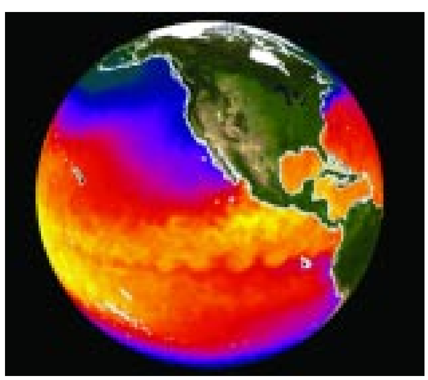


Figure 117: The Animated Earth is just one of the education components of NASA's Learning Technologies Project, which uses both new and entrenched technologies to provide education tools for science and math. This image uses NASA Earth science data to show global sea-surface temperatures.

In FY 2004, NASA also reviewed existing learning technologies and selected ten cognitive tools to include in the NASA-sponsored Classroom of the Future's Virtual Design Center. The Classroom of the Future also analyzed two thinking tools, visual ranking and seeing reason, developed by the Intel Education Foundation. The Virtual Design Center Editorial Board (a group of world-class researchers in educational psychology, learning sciences, and instructional technology), favorably reviewed the tools and both will be added to the Virtual Design Center. As part of the Classroom of the Future program, NASA also is planning empirical studies examining the benefits of three-dimensional visualization, comparative interfaces, graph sonification, and virtual data collection.

Another activity contributing to this Outcome was NASA's participation in the Summer 2004 National Science Teachers Association Retreat on the topic of "Anticipating the Role of Emerging Technologies in Science Education." Fifteen leaders in the field of science education and educational technology, including educators and representatives from NASA's Office of Education, attended the three-day retreat. Representatives from the following institutions also attended: Intel Research, Microsoft Research, Harvard University, Texas Instruments, the University of Georgia, the Education Development Center, Inc., Stanford University, University of Michigan, Concord Consortium, and Vernier, Inc.

Outcome 6.4.2: By 2008, demonstrate the effectiveness of NASA digital content materials in targeted learning environments.

NASA made progress toward this Outcome by using a university-developed survey assessment, the Teaching, Learning, and Computing Instrument, to evaluate materials used with the Explorer Schools Program. The comprehensive evaluation is a major component of the Explorer Schools program. Although the APG 4ED19 specifically refers to the School Technology And Readiness (STAR) tool for conducting the assessment, NASA instead used the Teaching, Learning, and Computing Instrument to capture the parts of the STAR instrument that were most relevant for NASA's Explorer Schools. As part of this process, NASA conducted a technology assessment at 47 of the 50 Explorer Schools. The results indicated that the majority of schools had limited technical capacity. Less than one-third of the schools had onsite technical support; less than ten percent had videoconferencing equipment. Through a partnership with ClearOne Communications, many of the Explorer Schools now have donated videoconferencing equipment to meet the needs identified by the technology survey. The Teaching, Learning, and Computing survey is available online through the Wheeling Jesuit University's Center for Educational Technologies.

Outcome 6.4.3: By 2008, establish a technology infrastructure that meets citizen demand for NASA learning services.

NASA performed several different surveys and assessments to capture the current state, needs, and recommendations from an array of NASA assets and customers. NASA is using the findings to make ongoing improvements to infrastructure and to identify necessary tasks and activities for implementation in FY 2005. Examples include the following:

- The University of Texas–El Paso completed a technology survey of the NASA Center Education Offices infrastructure.
- Over 65 Educator Resource Centers within NASA's network participated in a technology survey.
- The Center for Educational Technologies completed the Teaching, Learning, and Computing Survey on the NASA Explorer Schools sites.
- NASA conducted a user survey on NASA Television, its current usage and its projected usage if the format was digital.
- NASA continues to conduct an ongoing user survey utilizing the ForeSee Survey instrument.

Performance Measures for Objective 6.4		2004 Rating	Past Years' Performance Measures and Ratings	2003	2002	2001
Outcome 6.4.1	By 2008, identify and implement 4 new advanced technology applications that will positively impact learning.	green		Outcomes originated in FY 2004		
APG 4ED18	Benchmark advanced technology tools/applications under development to determine the 4–6 with the most impact potential for NASA e-learning.	green		none	none	none
Outcome 6.4.2	By 2008, demonstrate the effectiveness of NASA digital content materials in targeted learning environments.	green		Outcomes originated in FY 2004		
APG 4ED19	Assess at least 25 of the NASA explorer schools, utilizing the School Technology and Readiness (STaR) tool.	green		none	none	none
Outcome 6.4.3	By 2008, establish a technology infrastructure that meets citizen demand for NASA learning services.	green		Outcomes originated in FY 2004		
APG 4ED20	Perform a NASA learning services technology infrastructure needs assessment.	green		none	none	none

Goal 7
Engage the public in shaping and sharing the experience of exploration and discovery.

OBJECTIVE 7.1

Improve public understanding and appreciation of science and technology, including NASA aerospace technology, research, and exploration missions.

WHY PURSUE OBJECTIVE 7.1?

As NASA pursues its exploration goals, the Agency seeks to engage the public by communicating the benefits of its scientific discoveries, technological breakthroughs, and spinoffs relevant to the daily lives of all citizens. To do this, NASA is creating and leveraging informal partnerships to share the Agency's discoveries and experiences. These new, informal partners include science

Figure 118: A family takes a close look at the displays at NASA's Centennial of Flight exhibit, held in December 2003 in Kitty Hawk, North Carolina.

centers, museums, planetariums, community-based organizations, and other public forums. NASA also is working with all Agency partners to develop and disseminate educational materials that incorporate new discoveries. In addition, NASA will continue to work with these partners to create and deliver professional development programs for educators. A more science-literate society can make better decisions to define the technological developments that will shape the future.

NASA'S PROGRESS AND ACHIEVEMENTS IN FY 2004

Outcome 7.1.1: By 2008, establish a national program to engage the informal education community with NASA Science and Technology.

In FY 2004, NASA made excellent progress in engaging the informal education community through a number of collaborative initiatives. First, Northwestern University developed two reports (*American Attitudes toward Space Exploration and Attitudes of Space Policy Leaders*) assessing public perceptions and the needs of the informal community. Second, NASA sponsored a research project that created a database containing ten years of community attitudes and survey results. Third, NASA conducted focus groups in eight locations across the country, and the Center for Cultural Studies and Analysis also conducted a cultural analysis for NASA (*American Perception of Space Exploration*). Finally, NASA issued a grant to Dr. Sally Ride to develop baselines and begin evaluation strategies for the Sally Ride Festivals, which bring together hundreds of middle-school girls for a festive day of science and inspiration.

Outcome 7.1.2: By 2008 provide instructional materials derived from NASA research and scientific activities that meet the needs of NASA's informal education partners.

In FY 2004, NASA made progress in this area through a number of initiatives. The Agency developed a baseline of resources for the informal community. In addition, the American Museum of Natural History surveyed over 200 NASA resources to determine their usefulness to the informal education community. NASA also created, in association with over 130 organizations, the Mars Museum Visual Alliance to provide access to, and use of, data, images, and live updates from NASA's Mars rovers. NASA also helped the Denver Museum of Nature and Science develop Space Odyssey programs. Finally, NASA worked with the Challenger Learning Center to develop the Journey through the Universe program.

Outcome 7.1.3: By 2008 provide professional development for NASA's informal education partners.

NASA has implemented six Explorer Institutes to provide professional development opportunities for informal educators, and the Institutes are developing an inventory of resources available to the informal education community through NASA's Centers. NASA's partners in supporting the Institutes include: National Park Service, University of California at Berkeley, DePaul University, Southeast Regional Clearing House, Girl Scouts of the USA, Space Telescope Science Institute, Harvard–Smithsonian Astrophysical Observatory, Florida Space Grant Consortium, Kennedy Space Center Visitor Complex, Space Center Houston, Maryland Science Center, Science Museum of Minnesota, New England Aquarium, Northwestern University, Society for Amateur Scientists, North Carolina 4H clubs, Virginia Air and Space Center, and the Return to Flight Museum Commission. NASA also issued a Cooperative Agreement Notice to provide members of the informal education community with an opportunity to compete for funding support to host NASA Explorer Institute Focus Groups. These Focus Groups will assemble experts from the informal education community to further identify strategies and approaches that can be used to implement the NASA Explorer Institutes Program.

Outcome 7.1.4: Engage the public in NASA missions, discoveries and technology through public programs, community outreach, mass media, and the Internet.

Every NASA organization is charged with engaging the public in NASA's missions, discoveries, and technology through public outreach. As always, the Agency's outreach initiatives in FY 2004 touched the public at every level and ignited citizen interest in, and support for, the Nation's space program.

Many of NASA's public outreach activities in FY 2004 focused on the landings of the two Mars rovers:

- Through the Mars Visualization Alliance, more than a hundred science centers, museums, and planetariums brought the excitement of the Mars landings and the subsequent science explorations to the public in near-real-time through special events held at each of their facilities.
- The Passport to Knowledge series followed the progress of the Mars rovers through a series of special broadcasts for the education community and the general public.
- On January 17, "First Look" was broadcast live from the Houston Museum of Natural Science and NASA's Jet Propulsion Laboratory. Coming shortly after the January 3 landing of the first rover, *Spirit*, the program focused on the initial science activities conducted by the rover.
- On May 1, the St. Louis Science Center and NASA's Jet Propulsion Laboratory broadcast "New Views from Mars," an update on Mars Exploration Rover science on participating PBS stations and NASA Television as a service to science centers, schools, and non-commercial media.
- A new version of the "MarsQuest" exhibition, featuring the latest discoveries from the Mars rovers and a new Mars exhibit called "Destination Mars," began its national tour at the New Detroit Science Center in Detroit, Michigan. Saturn took center stage in July, with the Cassini–Huygens spacecraft arriving at Saturn and entering into an orbit around the ringed planet. For this event, the Mars Visualization Alliance transformed into the Saturn Alliance, giving the participating science centers, museums, and planetariums opportunities to hold special events to monitor and celebrate Cassini's orbital insertion, and the subsequent scientific explorations of Saturn and its moons.

Cassini's arrival at Saturn also provided exciting outreach opportunities, including the "Ringworld" planetarium show, a major feature at many participating planetariums around the country during the major Cassini mission events in FY 2004.

In addition to the Mars rovers and Cassini mission successes, an exceedingly rare celestial event occurred in FY 2004—the transit

Credit: NASA/T. Cline

Figure 119: A rare transit of Venus across the face of the Sun provided education opportunities on subjects ranging from the size of the solar system to the scale of the entire universe.

of Venus across the Sun. Starting at sunrise on June 8, 2004, Venus was visible to properly prepared viewers as it moved across the face of the early morning sun. The Venus Transit offered researchers, scientists, and educators the opportunity to highlight the historical significance of such an event in making scientific observations that range from studying the atmosphere of Venus to determining the distance scale of the universe. NASA made a number of resources available to students and teachers: a NASA/CONNECT television program about how the transit of Venus set the scale of the solar system; a Student Observation Network laboratory experiment on determining the distance from Earth to the Sun using transit observations; and multi-curricular resources in science, math, history, literature, arts, and music. In addition, the entire transit was Webcast by the Exploratorium from a site in Athens, Greece, and "Chasing Venus," a special exhibition featuring materials and historical documents from past transits compiled by the Dibner Library of the Smithsonian Institution, was on display at the National Museum of American History.

NASA also ignited public interest with Earth science-related outreach activities that included the Earth Observatory Web site (www.earthobservatory.nasa.gov), which posted 178 feature stories and 60 reference articles in FY 2004. In addition, NASA issued more than 70 press releases dealing with Earth science news stories.

As always, NASA had a successful year exciting public interest in space operations, increasing by more than ten percent the venues that provided "hands-on" opportunities for the public to engage in and understand the benefits of space flight and the International Space Station. The Agency reached and engaged an estimated audience of over four million people—two million more people than were reached in 2003. Examples of activities in this area include the following:

- The Astro Camp at Stennis Space Center, the Vision Station at Glenn Research Center, the photo opportunity exhibit, the Shuttle Launch Experience, and the Vision Exhibit at Marshall Space Flight Center provided highly interactive ways for visitors to learn about flight dynamics, landing the Shuttle, the International Space Station, space flight benefits, and Moon and Mars exploration.
- NASA participated in more than 780 Speaker's Bureau local, national, and international events, reaching estimated audiences in excess of 300,000. The Kennedy Space Center alone supported 348 Speaker's Bureau events reaching a total audience of nearly 130,000 people.
- NASA supported approximately 1,800 Astronaut Events as a result of Explorer School visits.
- NASA's Visitor's Centers welcomed approximately 1,831,287 visitors in FY 2004—about 40,000 more visitors than in FY 2003.
- NASA produced over 260,000 products related to space operations (e.g., feature articles, bookmarks, videos, fact sheets, postcards, and posters) compared to approximately 166,000 in FY 2003.
- In FY 2004, the Johnson Space Center and the Kennedy Space Center conducted over 200 media events that reached over 231,000,000 viewers, a 10 percent increase over FY 2003.

Figure 120: Members of the band Aerosmith encourage students to "Dream On" during their visit to Johnson Space Center in February 2004.

- In February 2004, the rock band Aerosmith toured the Johnson Space Center and recorded a public service announcement that aired on 12 major networks and reached millions of viewers around the world. The announcement featured space exploration imagery set to the track of Aerosmith's song "Dream On." The message from Steven Tyler, Aerosmith's lead singer, and Joe Perry, Aerosmith's lead guitarist, is that they have traveled all over the world and now NASA's rocket scientists are making it possible to travel to other worlds. Their message to the audience, specifically to students, was that "they will want to be part of this amazing journey, so study hard, stay in school and dream on."

Credit: T. Tschida

Figure 121: Eddie Patterson, a fourth-grade student at Tehachapi's Tompkins Elementary School, enjoyed "flying" a C-17 multi-engine aircraft simulator during Take Your Children to Work Day, held June 22, 2004, at NASA Dryden Flight Research Center, while Dryden engineer Ken Norlin and other students look on. NASA uses a variety of special events to communicate the adventures of flight and space exploration, and the benefits of NASA research and technology, to children and adults.

- NASA conducted International Space Station Trailer tours in 23 cities across the United States, reaching over 100,000 visitors.
- NASA staffed the Space Shuttle Launch Experience Theater at the Association of American Museums Annual Conference in New Orleans.

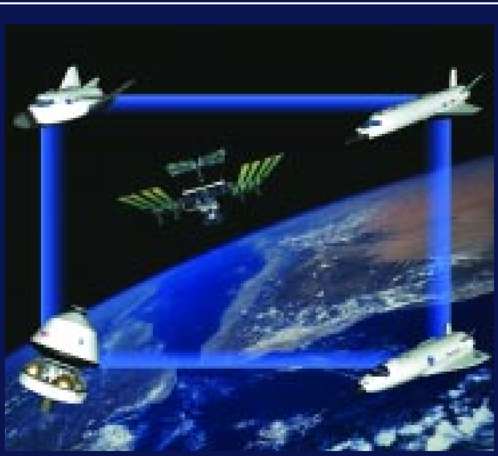
- NASA's Marshall Space Flight Center presented a "One NASA" Vision booth at the National Space Symposium in Colorado Springs. Approximately 2,000 conference attendees, representing government, military, and industry leaders, toured the exhibit.
- NASA participated in every major Centennial of Flight event featuring the Agency's new 10,000 square foot Centennial of Flight exhibit highlighting NASA's contributions to air and space flight and the Agency's ongoing work toward the future of flight and exploration.
- NASA developed an interactive educational display called *Edgarville Airport—Take Off to the Future of Air Travel*. Developed by NASA's Airspace Systems Program, this three-dimensional, interactive display provides a 180-degree, immersive environment using animated characters to guide users through a virtual airport. Real air traffic controllers explain how air traffic is managed, and the exhibit helps users understand how the National Airspace System operates.
- NASA sponsored space transportation exhibits at six events in FY 2004, reaching more than 113,000 participants: the Aerospace Sciences Meeting and Exhibit (2,500 participants); the National Space Symposium (3,000 participants); the Joint Propulsion Conference (2,000 participants); the Experimental Aircraft Association Oshkosh Airventure (6,000 participants); the Farnborough International Air Show (100,000 participants); and the Space Technology and Application International Forum (300 participants).
- NASA published and distributed three editions of *Aerospace Innovations*, including one special feature issue titled "NASA: Inspiring the Next Generation of Explorers Through Education."
- NASA published and distributed twelve issues of the *NASA Tech Briefs* magazine and the annual edition of *Spinoff*.
- In FY 2004, NASA made 21,467 new NASA technologies considered to be of benefit to U.S. industry available to the public through the NASA TechTracS online database (http://technology.nasa.gov). Technology descriptions include technical briefs, diagrams, and illustrations. This exceeds NASA's annual goal by about 19 percent.

Performance Measures for Objective 7.1		2004 Rating	Past Years' Performance Measures and Ratings	2003	2002	2001
Outcome 7.1.1	By 2008, establish a national program to engage the informal education community with NASA science and technology.	green		Outcomes originated in FY 2004		
APG 4ED23	Conduct an opinion survey to baseline public attitudes and knowledge of NASA research and exploration.	green		none	none	none
Outcome 7.1.2	By 2008 provide instructional materials derived from NASA research and scientific activities that meet the needs of NASA's informal education partners.	green		Outcomes originated in FY 2004		
APG 4ED21	Compile an inventory of existing programs and partnerships to establish a baseline to assess and prioritize high-leverage and critical informal education programs and educational family involvement activities.	green		none	none	none
Outcome 7.1.3	By 2008, provide professional development for NASA's informal education partners.	green		Outcomes originated in FY 2004		
APG 4ED22	Inventory and assess current NASA professional development programs for relevance to the targeted informal learning environments.	green		none	none	none
Outcome 7.1.4	Engage the public in NASA missions, discoveries, and technology through public programs, community outreach, mass media, and the Internet.	green		Outcomes originated in FY 2004		
APG 4AT16	Partner with external organizations to celebrate the centennial of powered flight highlighting NASA's accomplishments and activities in the advancement of flight.	green		none	none	none
APG 4AT17	Partner with museums and other cultural organizations and institutions to promote NASA achievements to non-traditional audiences, develop and implement a series of traveling exhibitions highlighting NASA activities, develop and distribute informational material related to accomplishments and plans.	green		none	none	none
APG 4ESA6	Provide in public venues at least 50 stories on the scientific discoveries, practical benefits, or new technologies sponsored by the Earth Science Enterprise.	green		none	none	none
APG 4ESS13	Post the most exciting imagery and explanations about Earth science on the Earth observations/ESE Web site.	green		3Y25 green	2Y24 green	1Y18 green
APG 4HRT11	Publish and distribute program specific publications (Aerospace Innovations, NASA Tech Briefs, Spinoff) including 1 industry targeted edition, in a sector where NASA can promise its technologies available for commercialization.	green		none	none	none
APG 4HRT12	Provide public and industry access to the TechTracS database, which features approximately 18,000 updated and evolving new technologies, as well as technical briefs, diagrams, and illustrations.	blue		none	none	none
APG 4RPFS10	Expand outreach activities that reach minority and under-represented sectors of the public, through increased participation in conferences and community events that reflect cultural awareness and outreach. Each fiscal year, increase the previous year baseline by supporting at least one new venue that focuses on these public sectors.	green		none	none	none
APG 4RPFS8	Increase distribution of the Space Research newsletter by 5,000 over FY03 circulation in order to further educate the general public, industry, and academia on space-based research.	green		3B12 green	2B14 green	none
APG 4RPFS9	Through collaboration with PAO, establish and sustain a series of media briefings highlighting OBPR research.	green		none	none	none
APG 4SFS3	Ensure participation of all space flight programs and Centers in increasing by 10% venues that provide "hands-on" opportunities for the public to experience and become more knowledgeable of space flight benefits and contributions, particularly ISS.	green		3H22 green	2H24 yellow	none
APG 4SSE20	Through partnerships with major science museums or planetariums, put on display or on tour major exhibitions or planetarium shows based on Theme content.	green		3S12 green	2S12 blue	1S9 green
APG 4SSE21	Provide materials and technical expertise to support the development of exhibits and programs at science museums and planetariums.	green		none	none	none
APG 4SSE22	Seek out and capitalize on special events and particularly promising opportunities in the Theme science program to bring space science to and involve the public in the process of scientific discovery.	green		none	none	none
APG 4TS4	Space transportation technical exhibits will be sponsored for at least five events reaching over 50,000 participants to improve public appreciation of the ongoing activities and benefits of NASA's space transportation research and technology development efforts.	green		none	none	none

As Only NASA Can: Exploration Capabilities

Goal 8: Ensure the provision of space access, and improve it by increasing safety, reliability, and affordability.

Goal 9: Extend the duration and boundaries of human space flight to create new opportunities for exploration and discovery.



Goal 10: Enable revolutionary capabilities through new technology.

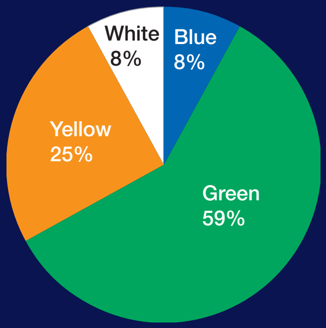
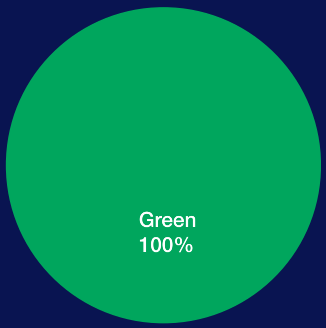


Figure 122:NASA achieved 67 percent of the APGs in Goal 8.



NASA is on track to achieve 100 percent of its Outcomes under Goal 8.

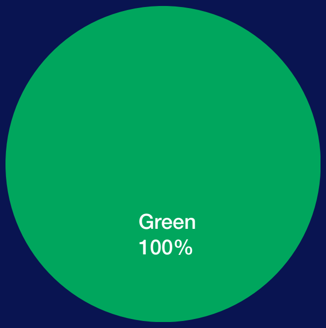
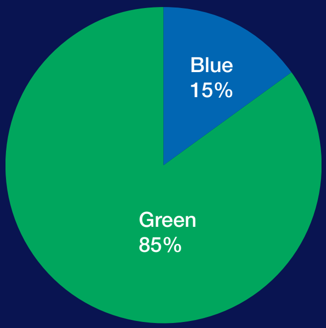


Figure 123: NASA achieved 100 percent of the APGs in Goal 9.



NASA is on track to achieve 100 percent of its Outcomes under Goal 9.

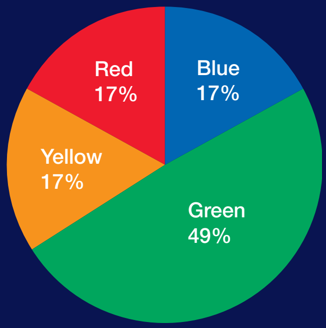
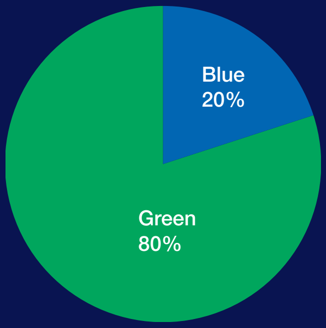


Figure 124: NASA achieved 66 percent of the APGs in Goal 10.



NASA is on track to achieve 100 percent of its Outcomes under Goal 10.

APG color ratings:

- Blue: Significantly exceeded APG
- Green: Achieved APG
- Yellow: Failed to achieve APG, progress was significant, and achievement is anticipated within the next fiscal year.
- Red: Failed to achieve APG, do not anticipate completion within the next fiscal year.
- White: APG was postponed or cancelled by management directive.

Outcome color ratings:

- Blue: Significantly exceeded all APGs. On track to exceed this Outcome as stated.
- Green: Achieved most APGs. On track to fully achieve this Outcome as stated.
- Yellow: Progress toward this Outcome was significant. However, this Outcome may not be achieved as stated.
- Red: Failed to achieve most APGs. Do not expect to achieve this Outcome as stated.
- White: This outcome as stated was postponed or cancelled by management directive or the Outcome is no longer applicable as stated based on management changes to the APGs.

Goal 8 Ensure the provision of space access, and improve it by increasing safety, reliability, and affordability.

OBJECTIVE 8.1

Assure safe, affordable, and reliable crew and cargo access and return from the International Space Station.

WHY PURSUE OBJECTIVE 8.1?

The Space Station is the largest science and technology cooperative program in history, drawing on the resources and scientific and engineering expertise of 16 nations. Since the Space Shuttle was grounded after the *Columbia* accident in February 2003, automated Russian Progress vehicles have resupplied the two-person Station crew as needed, and Russian Soyuz vehicles have transported crews safely and reliably to and from the Station. This level of cooperation has enabled a continuous crew presence on the Station.

Figure 125: An Expedition 9 crewmember photographed this Progress 14 vehicle as it approached the International Space Station on May 27, 2004. The unpiloted vehicle was delivering 2.5 tons of food and other supplies.

When the Shuttle fleet returns to flight, the overarching priority will be to complete construction of the U.S. and International phases of the International Space Station safely. In coordination with its partners, NASA will analyze requirements and resources for the Station and decide whether to provide an additional docking node. The partners also will determine how to optimize cargo transportation and resupply operations. NASA also will examine its ongoing reliance on Progress vehicles and evaluate potential commercial sources of transportation. NASA is assessing options to use domestic launch services to augment space access for Station cargo and crew requirements.

NASA'S PROGRESS AND ACHIEVEMENTS IN FY 2004

Outcome 8.1.1: Acquire non-Shuttle crew and cargo access and return capability for the Station by 2010.

Crew and cargo access for the International Space Station is provided using a mixed fleet strategy, including partner vehicles. While the Shuttle is grounded, Russian Soyuz and Progress vehicles provide crew and cargo transportation. In the future, the Launch Services Program will acquire high-quality launch services from commercial providers. NASA released a Request for Information in August 2004 to solicit information concerning available commercial space transportation services, including those needed for International Space Station cargo return services. In FY 2005, NASA will issue a Request for Proposals to begin the process of procuring crew and cargo re-supply services for the Station. To support this effort, the FY 2005 President's Budget includes a line providing for crew and cargo services. In addition, the European Automated Transfer Vehicle and the Japanese H-II Transfer Vehicle, both in development, will play a role in the future as part of a mixed fleet. At this time, only the Shuttle is capable of providing the necessary science cargo return services from the Station.

Credit: NASA/B. Ingalls

Figure 126: While the Shuttle is grounded, Russian Soyuz TMA-3 spacecraft have delivered crewmembers and visiting astronauts from the European Space Agency to the International Space Station. In this picture, a Soyuz spacecraft and its booster rocket, which will deliver the Expedition 8 crew to the Station, is lifted up from a rail car onto its launch pad at Baikonur Cosmodrome, Kazakhstan, on October 16, 2003.

Performance Measures for Objective 8.1		2004 Rating		2003	2002	2001
Outcome 8.1.1	Acquire non-Shuttle crew and cargo access and return capability for the Station by 2010.	green		Outcomes originated in FY 2004		

Note: no APGs in FY 2004; reporting at Outcome level only.

Note: Objective 8.2 was cancelled.

Goal 8 Ensure the provision of space access, and improve it by increasing safety, reliability, and affordability.

OBJECTIVE 8.3

Improve the accessibility of space via the Space Shuttle to better meet Space Station assembly, operations, and research requirements.

WHY PURSUE OBJECTIVE 8.3?

As explorers and pioneers, NASA's commitment to space exploration is firm. This includes robotic and human space flight, both of which are essential to the U.S. space program.

Figure 127: Crews help guide an airlock, hanging from a boom in the Orbiter Processing Facility at Kennedy Space Center, into *Discovery*'s bay on May 12, 2004. All three Shuttles have undergone extensive maintenance and safety upgrades to prepare them for return to flight.

The Space Shuttle has been the workhorse for the U.S. space program for more than two decades. The Shuttle of today, however, has evolved significantly from the Shuttle of 20 years ago. Although it looks the same on the exterior, the Shuttle has undergone continuous technological improvements.

NASA is developing an integrated system plan for the Shuttle to improve safety, reliability, and maintainability so that the fleet can better support the International Space Station. Throughout the Station's assembly phase, the Shuttle will be used primarily to lift new Station elements into orbit and meet ongoing Station logistics, resupply, and research requirements.

NASA'S PROGRESS AND ACHIEVEMENTS IN FY 2004

Outcome 8.3.1: Assure public, flight crew, and workforce safety for all Space Shuttle operations and safely meet the manifest and flight rate commitment through completion of Space Station assembly.

Throughout FY 2004, NASA focused on returning the Space Shuttle to safe flight to complete assembly of the International Space Station, consistent with the Vision for Space Exploration.

Figure 128: The Shuttle *Atlantis* rolls into the Orbiter Processing Facility at Kennedy Space Center on December 16, 2003, where it received routine maintenance, as well as upgrades and modifications recommended by the *Columbia* Accident Investigation Board.

NASA is complying with the recommendations of the *Columbia* Accident Investigation Board, as well as NASA-initiated "raise the bar" actions. NASA's *Implementation Plan for Space Shuttle Return to Flight and Beyond* documents the return to flight effort. The Plan is updated periodically to ensure that it accurately records the progress being made toward a safe return to flight.

A major aspect of the return to flight effort has been to address the technical, organizational, and procedural issues that led to the *Columbia* accident. This year, Space Shuttle program officials increased their understanding of the debris environment and the material characteristics of the orbiter and its Thermal Protection System. As a result, NASA has targeted critical areas for orbiter hardening prior to return to flight. To facilitate on-orbit inspections of areas of the Shuttle that are not visible using just the Shuttle Remote Manipulator System, NASA is installing a newly-developed Orbiter Boom Sensor System to inspect critical areas of the Shuttle's exterior. NASA also is developing viable repair techniques and materials for the Thermal Protection System, and the Agency made progress in developing materials and procedures for repairing tile and reinforced

Carbon-Carbon in flight. The Space Shuttle and International Space Station programs also have made progress in defining and planning for a Contingency Shuttle Crew Support capability to sustain a Shuttle crew on the International Space Station if a rescue mission is ever needed.

The Stafford-Covey Task Group assessed NASA's implementation of the Columbia Accident Investigation Board's return to flight recommendations and other technical issues and conditionally closed five of the Board's 15 return to flight recommendations.

The following table shows all 15 return to flight recommendations of the Columbia Accident Investigation Board and NASA's compliance status as of September 30, 2004.

CAIB RTF Recommendations		NASA Response	Status
3.2-1	Initiate an aggressive program to eliminate all External Tank Thermal Protection System debris-shedding at the source with particular emphasis on the region where the bipod struts attach to the External Tank.	NASA has completed several assessments of debris sources and sizes from the External Tank. A comprehensive testing program to understand the root causes of foam shedding is nearly complete. Bipod Ramp and LO2 Feedline Bellows drip lip redesigns are complete and going through validation and verification.	In Work
3.3-2	Initiate a program designed to increase the Orbiter's ability to sustain minor debris damage by measures such as improved impact-resistant Reinforced Carbon-Carbon and acreage tiles. This program should determine the actual impact resistance of current materials and the effect of likely debris strikes.	NASA has initiated an Orbiter hardening program to increase the Orbiter's capability to sustain minor debris damage. NASA identified 8 different design families and then grouped work into 3 categories based on when work should be completed. All Phase I or RTF requirements will be implemented before RTF. These included front spar protection on the wings RCC panels, main landing gear door thermal barrier protection and elimination of bonded studs from the Forward Reaction Control System. Other modifications are underway.	In Work
3.3-1	Develop and implement a comprehensive inspection plan to determine the structural integrity of all Reinforced Carbon-Carbon system components. This inspection plan should take advantage of advanced non-destructive inspection technology.	The Space Shuttle program is pursuing inspection capability improvements using newer technologies to allow comprehensive nondestructive inspection of the Reinforced Carbon-Carbon outer coating and internal structure, and without removing it from the vehicle.	Conditionally closed by Stafford-Covey Task Group
3.4-1	Upgrade the imaging system to be capable of providing a minimum of three useful views of the Space Shuttle from liftoff to at least Solid Rocket Booster separation, along any expected ascent azimuth. The operational status or these assets should be included in the Launch Commit Criteria for future launches. Consider using ships or aircraft to provide additional views or the Shuttle during ascent.	NASA has increased the total number of ground cameras and added additional short-, medium-, and long-range camera sites. NASA has approved the development and implementation of an aircraft-based imaging system known as the WB-57 Ascent Video Experiment (WAVE) to provide both ascent and entry imagery. NASA is optimizing launch requirements to support the ability to capture three complementary views of the Shuttle and adding launch commit criteria to assure imaging capabilities for critical control systems and data collection nodes. NASA has also confirmed that existing launch requirements relating to weather constraints support camera coverage requirements.	In Work
3.4-2	Provide a capability to obtain and downlink high-resolution images of the External Tank after it separates.	NASA is completing test and verification of the performance of a new digital camera in the Orbiter's umbilical well. Orbiter design engineering and modifications to provide this capability are underway on all three vehicles.	In Work
3.4-3	Provide a capability to obtain and downlink high-resolution images of the underside on the Orbiter wing leading edge and forward section of both wings' Thermal Protection System.	For the first few missions, NASA will use primarily on-orbit inspections to meet the requirement to assess the health and status of the Orbiter's TPS. This will be accomplished by using a number of imagery sources including cameras on the External Tank and Solid Rocket Boosters. NASA's long-term strategy will include improving on-vehicle ascent imagery and the addition of an impact detection sensor system on the Orbiter.	In Work
4.2-1	Test and qualify the flight hardware bolt catchers.	NASA has completed the redesign of the bolt catcher assembly, the redesign and resizing of the ET attachment bolts and inserts, the testing to characterize the energy absorber material, and the testing to determine the design loads. NASA is completing structural and thermal protection material qualification testing.	In Work

CAIB RTF Recommendations		NASA Response	Status
4.2-3	Require that at least two employees attend all final closeouts and intertank area hand-spraying procedures.	NASA has established a TPS verification team to verify and validate all future foam processes. In addition, the Material Processing Plan will define how each specific part closeout on the External Tank will be processed. Additionally, the Shuttle Program is documenting the requirement for minimum two-person closeouts for all major flight hardware elements (Orbiter, External Tank, Solid Rocket Booster, Solid Rocket Motor, extravehicular activity, vehicle processing, and main engine).	Conditionally closed by Stafford-Covey Task Group
4.2-5	Kennedy Space Center Quality Assurance and United Space Alliance must return to the straightforward, industry-standard definition of "Foreign Object Debris" and eliminate any alternate or statistically deceptive definitions like "processing debris."	The Kennedy Space Center has completed work to establish a revitalized program for identifying and preventing foreign object debris that surpasses the CAIB's recommendation.	Conditionally closed by Stafford-Covey Task Group
6.2-1	Adopt and maintain a Shuttle flight schedule that is consistent with available resources. Although schedule deadlines are an important management tool, those deadlines must be regularly evaluated to ensure that any additional risk incurred to meet the schedule is recognized, understood, and acceptable.	NASA is developing a process for Shuttle launch schedules that incorporates all of the manifest constraints and allows adequate margin to accommodate a normalized amount of changes. This process entails building in launch margin, cargo and logistics margin, and crew timeline margin. The Shuttle program is examining the risk management process and tools that assess technical, schedule, and programmatic risks. Risk data will be displayed on the One-NASA Management Information System. Senior managers can virtually review schedule performance indicators and risk assessments on a real-time basis.	In Work
6.3-1	Implement an expanded training program in which the mission Management Team faces potential crew and vehicle safety contingencies beyond launch and ascent.	NASA's response is being implemented in two steps: 1) review and revise Mission Management Team processes and procedures; and 2) develop and implement a training program consistent with those process revisions. Both of these activities are in work.	In Work
6.3-2	Modify the Memorandum of Agreement with the National Imagery and Mapping Agency to make the imaging of each Shuttle flight while on orbit a standard requirement.	NASA has concluded a Memorandum of Agreement with the National Imagery and Mapping Agency (subsequently renamed the National Geospatial-Intelligence Agency) and has initiated discussions with other agencies to explore the use of appropriate national assets to provide for on-orbit assessments of the condition of each Orbiter vehicle.	Conditionally closed by Stafford-Covey Task Group

6.4-1	For missions to the International Space Station, develop a practicable capability to inspect and effect emergency repairs to the widest possible range of damage to the Thermal Protection System, including both tile and Reinforced Carbon-Carbon, taking advantage of the additional capabilities available when near to or docked at the International Space Station. For non-Station missions, develop a comprehensive autonomous (independent of Station) inspection and repair capability to cover the widest possible range of damage scenarios. Accomplish an on-orbit Thermal Protection System inspection, using appropriate assets and capabilities, early in all missions. The ultimate objective should be fully autonomous capability for all missions to address the possibility that an International Space Station mission fails to achieve the correct orbit, fails to dock successfully, or is damaged during or after undocking.	Thermal Protection System (TPS) inspection and repair represent one of the most challenging and extensive RTF tasks. NASA has defined preliminary inspection requirements. Testing and analyses continue to determine the best sensors to detect TPS damage. The Reinforced Carbon-Carbon (RCC) repair project is pursuing two complementary repair concepts that together will enable repair of RCC damage: Plug Repair and Crack Repair. NASA has made significant progress in developing tile repair processes and repair material. Detailed thermal analyses and testing are underway to confirm the material can be applied and cured in the full range of orbit conditions. NASA is also developing EVA tools and techniques for TPS repair. Experiences gained through complex International Space Station construction tasks are contributing to NASA's ability to meet this challenge. In addition to planned TPS repair capability, special on-orbit tests are under consideration for STS-114 to further evaluate TPS repair materials, tools, and techniques.	In Work
9.1-1	Prepare a detailed plan for defining, establishing, transitioning, and implementing an independent Technical Engineering Authority, independent safety program and a reorganized Space Shuttle Integration Office.	Although the CAIB recommendation only requires preparation of a detailed plan prior to return to flight, NASA concluded that this important issue requires prompt implementation. Planning for these organizational changes is underway.	In Work
10.3-1	Develop an interim program of closeout photographs for all critical sub-systems that differ from engineering drawings. Digitize the closeout photograph system so that images are immediately available for on-orbit troubleshooting.	NASA has also created a robust system for photographing, archiving, and accessing closeout photography for the Space Shuttle. This system will allow key users across the Agency to quickly and easily access images of the Shuttle systems to make operational decisions during a mission and support postflight assessments.	Conditionally closed by Stafford-Covey Task Group

Performance Measures for Objective 8.3		2004 Rating	Part Years' Performance Measures and Ratings	2003	2002	2001
Outcome 8.3.1	Assure public, flight crew, and workforce safety for all Space Shuttle operations and safely meet the manifest and flight rate commitment through completion of Space Station assembly.	green		Outcomes originated in FY 2004		
APG 4SSP1	Implement necessary modifications to the Space Shuttle system for return-to-flight in FY 2004.	yellow		3H05 red	2H6 green	1H7 green
APG 4SSP2	Achieve zero Type-A (damage to property at least $1M or death) or Type-B (damage to property at least $250K or permanent disability or hospitalization of 3 or more persons) mishaps in FY 2004.	yellow		3H06 red	2H7 green	1H30 green
APG 4SSP3	Achieve 100% on-orbit mission success for all Shuttle missions launched in FY 2004. For this metric, mission success criteria are those provided to the prime contractor (SFOC) for purposes of determining successful accomplishment of the performance incentive fees in the contract.	white		3H08 green	2H09 green	1H6 yellow

Note: See NASA's Performance Improvement Plan at the end of Part 2 for details on FY 2004 APGs and Outcomes rated Red, Yellow, or White.

Goal 8 Ensure the provision of space access, and improve it by increasing safety, reliability, and affordability.

OBJECTIVE 8.4

Assure capabilities for world-class research on a laboratory in low Earth orbit.

WHY PURSUE OBJECTIVE 8.4?

When completed, the International Space Station will include more space for research than any spacecraft ever built. It accommodates public- and private-sector research in biological and physical sciences, Earth and space observations, and technology development. It also houses research that will make future human space exploration possible.

Figure 129: Expedition crewmember Edward M. (Mike) Fincke conducts one of several tests for the Capillary Flow Experiment in the Destiny Laboratory on September 18, 2004.

Working with its international partners, NASA is managing resources to maximize the research potential on the Station, including optimizing the crew size in the near and long term.

When the Shuttle fleet returns to flight, NASA will resume International Space Station construction. The Agency also will deliver research facilities to the Station, like the second Human Research Facility, as well as a full complement of research payloads to get the Station back up to full research capacity. In addition, NASA is exploring new ways to enhance Station research, such as analyzing whether the Shuttles can be modified to provide extended Station stays to enable additional research capabilities.

NASA'S PROGRESS AND ACHIEVEMENTS IN FY 2004

Outcome 8.4.1: Provide a safe, reliable, and well-managed on-orbit research facility.

The International Space Station Program has provided a safe, reliable, and well-managed on-orbit research facility. On July 23, 2004, the International Partners revised the baseline for the Station's Assembly and endorsed the Multilateral Coordination Board-recommended configuration. The Station partners are working on plans to provide the services necessary to support the Station's crew and cargo transportation. The Shuttle's return to flight is scheduled for no earlier than May 2005.

Figure 130: Expedition 8 Flight Engineer Alexander Y. Kaleri performs maintenance on the Treadmill Vibration Isolation System in the Zveda Service Module on November 23, 2003.

In FY 2004, there were no Type-A mishaps (an occurrence or event that causes death or damages to equipment or property equaling to $1 million or more). There was one Type-B mishap on the ground at a sub-contractor facility in October 2003. (A Type-B mishap is an occurrence or event that causes permanent disability, hospitalizes three or more people, or causes damage to equipment or property equal to or greater than $250,000, but less than $1 million.) A spare cupola window was crushed at the Dow Corning plant. Although damage was estimated at $300,000, there were no injuries. The final mishap investigation report is in concurrence.

Since the Space Shuttle was grounded in February 2003, the planned science activities have been limited by the reduced crew size and transport capabilities of the Russian Progress and Soyuz spacecraft. However, NASA minimized the impact of these limitations by re-planning and rescheduling science activities, and, as a result, the Expedition 8 crew conducted 276 hours of research, operating 138 percent of the re-planned investigations. The crew initiated four new investigations and continued 18 investigations.

In FY 2004, overall International Space Station systems performance surpassed expectations in light of the grounding of the Space Shuttle fleet. For example, the International Space Station crew was able to repair the Treadmill Vibration Isolation System gyro on-orbit instead of returning it to Earth for repairs. In addition, the crews completed two-person extravehicular activities safely and successfully without a crewmember inside the Station.

If NASA is to fulfill the Vision for Space Exploration, a vision that depends on full utilization of the Station's facilities and capabilities, contingency plans for Station logistics and maintenance services are critical. NASA and the Agency's international partners have learned a great deal functioning with a crew of two persons, lessons that will enable realistic contingency planning and enhance future exploration initiatives.

Outcome 8.4.2: Expand the ISS crew size to accommodate U.S. and International Partner research requirements.
The international partnership, through a Multilateral Program Partner Team reporting directly to the Multilateral Coordination Board, evaluated options for the International Space Station on-orbit configuration. This team principally explored options related to accommodating a crew greater than three and the associated advanced life support systems, habitability elements, and rescue vehicles necessary to meet utilization mission requirements for an increased crew size. The Heads of Agency endorsed the Board-recommended Station configuration on July 23, 2004, a configuration that will accommodate a larger on-orbit crew.

Performance Measures for Objective 8.4		2004 Rating	Past Years' Performance Measures and Ratings	2003	2002	2001
Outcome 8.4.1	Provide a safe, reliable, and well-managed on-orbit research facility.	green		Outcomes originated in FY 2004		
APG 4ISS2	Achieve zero Type-A (damage to property at least $1M or death) or Type-B (damage to property at least $250K or permanent disability or hospitalization of 3 or more persons) mishaps in FY 2004.	yellow		3H11 green	2H10 green	none
APG 4ISS3	Based on the Space Shuttle return-to-flight plan, establish a revised baseline for ISS assembly (through International Core Complete) and research support.	green		3H02 yellow	none	none
APG 4ISS4	Provide at least 80% of up-mass, volume and crew-time for science as planned at the beginning of FY 2004.	green		none	none	none
Outcome 8.4.2	Expand the ISS crew size to accommodate U.S. and International Partner research requirements.	green		Outcomes originated in FY 2004		
APG 4ISS5	Obtain agreement among the International Partners on the final ISS configuration.	green		none	none	none

Note: See NASA's Performance Improvement Plan at the end of Part 2 for details on FY 2004 APGs and Outcomes rated Red, Yellow, or White.

Goal 8 Ensure the provision of space access, and improve it by increasing safety, reliability, and affordability.

OBJECTIVE 8.5

Provide services for space communications, rocket propulsion testing, and launch in support of NASA, other government agencies and industry.

WHY PURSUE OBJECTIVE 8.5?

Safe and successful space flight relies on a variety of technologies and support services, including communication networks, rocket test facilities, and launch services. Dependable communications

Figure 131: A 750,000 pound-thrust rocket engine undergoes a test firing at Marshall Space Flight Center.

are vital to the success of all human and robotic space missions. Mission controllers, astronauts, and scientists depend on communications networks to monitor spacecraft, intercede when problems arise, and share technical and scientific data. NASA continuously improves the Agency's space communications networks to increase compatibility among network nodes and streamline current and projected requirements for network connectivity, security, and manageability. NASA, in cooperation with other government agencies, is developing space communication architectures to meet the needs of future exploration.

NASA also operates, maintains, and enhances test facilities to test rocket engines and engine components used in current flight vehicles and future rocket propulsion technologies and systems. These facilities are available to NASA researchers, other government agencies, and industry.

In addition, NASA will continue to work with government and industry partners to ensure that resources are available to meet the Nation's space launch needs. NASA ensures that its internal customers, as well as its government and commercial customers, have access to all available launch services, including the Space Shuttle, commercial and Department of Defense launch vehicles, and foreign launch services.

NASA'S PROGRESS AND ACHIEVEMENTS IN FY 2004

Outcome 8.5.1: Provide safe, well-managed and 95% reliable space communications, rocket propulsion testing, and launch services to meet agency requirements.

Space Communications

Reliable and consistent space communications are critical for the success of any mission outside of Earth's gravity. Without it, astronauts and cosmonauts onboard the International Space Station would be unable to communicate with Earth and to retrieve and send scientific data to researchers. NASA's Space Network is the primary source of connectivity for the Station and Space Shuttle. If, for any reason, this network should become unavailable, the Russian network can provide communications only while the space vehicles are over Russia. The Space Network and NASA Integrated Services Network have continuously provided superb connectivity for all customers, and the connectivity proficiency of both networks consistently has exceeded 99 percent. The Space Network serves a number of science missions including Aqua, Aura, Gravity Probe-B, the Hubble Space Telescope, and Terra. The success of future missions to the Moon and Mars will rely on this same exceptional level of space communications support. To meet the communications requirements of the Vision for Space Exploration, NASA created the Space Communications Architecture Working Group, which will be responsible for establishing the NASA-wide baseline space communications architecture, including a framework for possible deep-space and near-Earth laser communications services.

Rocket Propulsion

NASA tests rocket propulsion and flight certifies rocket propulsion systems for the Space Shuttle and future generations of space vehicles. All Space Shuttle Main Engines must pass a series of test firings prior to being installed in the back of the orbiter. The Rocket Propulsion Testing program at the Stennis Space Center provides propulsion testing for the Marshall Space Flight Center in Huntsville, Alabama, the White Sands Test Facility near Las Cruces, New Mexico, and others. All Rocket Propulsion Testing Program customers indicated a positive assessment of the support provided by the program in surveys conducted during the past year. The Rocket Propulsion Testing Program managed this level of support while maintaining an excellent record of zero Type-A or Type-B mishaps in FY 2004.

Program successes in FY 2004 included enabling the Space Shuttle Main Engine to surpass a remarkable level of one million seconds of successful test and launch firings.

Another major highlight in FY 2004 occurred on October 23, 2003, when Space Shuttle Program contractor ATK Thiokol Propulsion successfully conducted the first static test firing of a five-segment Space Shuttle Reusable Solid Rocket Motor. The test was part of an ongoing safety program to verify material and manufacturing processes. The five-segment motor pushed various features of the motor to their limits so engineers could validate the safety margins of the four-segment motors currently used to launch the Space Shuttle. The new five-segment motor has about a ten-percent-greater capability than the four-segment motor and could increase the Space Shuttle's payload capacity by 23,000 pounds.

Launch services

In the area of launch services for NASA's robotic space science research missions, NASA facilitated the successful launch of three science research missions in FY 2004—a 100 percent success rate for missions on the FY 2004 Expendable Launch Vehicle manifest. The three missions were as follows:

Figure 132: A Delta II rocket, carrying the MESSENGER spacecraft, waits on the launch pad at Kennedy Space Center on August 2, 2004, after its early-morning launch was scrubbed due to weather. The rocket and its spacecraft passenger successfully launched the next morning around 2:15 am EDT.

- Gravity Probe B, successfully launched on April 20, 2004, will answer questions raised about Einstein's General Theory of Relativity;
- Aura, part of the Earth Observing System, successfully launched on July 15, 2004, on a mission to study Earth's climate change and air quality; and
- The MESSENGER spacecraft, successfully launched on August 3, 2004, will travel over the next 6.5 years to the innermost planet of our solar system, Mercury, where it will study the planet's geography and climate to understand its history and significance in the solar system.

All three missions were launched using Boeing Delta II rockets, acquired commercially through NASA launch services contracts. The Launch Services Program is committed to providing assured access to space for NASA's robotic science missions and to enabling the continued exploration of the solar system. These activities, vital to the Agency's mission, would not be possible without consistently superior launch services. NASA's Launch Services Program partners with other Federal agencies, including the United States Air Force and the Federal Aviation Administration, to ensure that customers have access to space and that range safety is a high priority.

Performance Measures for Objective 8.5		2004 Rating	Past Years' Performance Measures and Ratings	2003	2002	2001
Outcome 8.5.1	Provide safe, well-managed and 95% reliable space communications, rocket propulsion testing, and launch services to meet Agency requirements.	green		Outcomes originated in FY 2004		
APG 4SFS4	Maintain NASA success rate at or above a running average of 95% for missions on the FY 2004 expendable launch vehicle (ELV) manifest.	green		3H03 blue	2H3 green	none
APG 4SFS5	Achieve at least 95% of planned data delivery for the International Space Station, each Space Shuttle mission, and low Earth orbiting missions in FY 2004.	blue		3H14 blue	none	none
APG 4SFS6	Achieve zero Type-A (damage to property at least $1M or death) or Type-B (damage to property at least $250K or permanent disability or hospitalization of 3 or more persons) mishaps in FY2004.	green		3H04 blue	none	none
APG 4SFS7	Achieve positive feedback from a minimum of 95% of all rocket propulsion test customers.	green		none	none	none
APG 4SFS8	Establish the Agency-wide baseline space communications architecture, including a framework for possible deep space and near-Earth laser communications services.	green		none	none	none

Goal 9
Extend the duration and boundaries of human space flight to create new opportunities for exploration and discovery.

OBJECTIVE 9.1

Understand human physiological reactions to reduced gravity and develop countermeasures to assure survival of humans traveling far from Earth.

WHY PURSUE OBJECTIVE 9.1?

For over 40 years, NASA has been sending astronauts into space, and during this time, researchers have sought to understand gravity in the physical universe and its impact on life. Scientists now understand that biological systems undergo changes during short- and long-term space travel—changes that still are not fully understood. Researchers do know that some of the physiological changes that occur in microgravity are not problematic during space flight, but are potentially risky upon return to Earth or another gravitational environment, like the surface of Mars. Therefore, humankind's eventual long-term travel beyond Earth's orbit requires further research to fully explain these changes and prepare explorers for the challenges and risks they will face in new space environments.

Figure 133: Expedition 8 crewmember Michael Foale runs on the Treadmill Vibration Isolation System, with the help of a bungee harness, in the Zveda Service Module on April 12, 2004. The crew has a variety of exercise equipment to help them prevent some of the muscle loss that occurs in the near-weightlessness (also called microgravity) of Earth orbit.

NASA is conducting ground- and space-based research to identify and mitigate the changes that occur to the body—like bone loss, muscle atrophy, and changes to the cardiovascular and sensory systems—in various gravitational environments. The International Space Station is serving as a platform to study these changes over long periods and to test medications and technologies that could serve as countermeasures.

NASA'S PROGRESS AND ACHIEVEMENTS IN FY 2004

Outcome 9.1.1: By 2008, develop and test candidate countermeasures using ground-based analysis and space flight.

To prepare astronauts for the rigors of space travel, NASA provides medical preparation, protection from the hazards of space travel, and methods to help them stay fit and improve their performance while in space. NASA does this by researching critical health and safety risks, developing solutions to enable informed decision-making, and maintaining a Critical Path Roadmap to guide research priorities for human space flight. Currently funded research experiments include Dr. Nick Kanas's "Crewmember and Crew–Ground Interactions During International Space Station Missions," which addresses human performance, interpersonal relationships, team cohesiveness, and group dynamics during long missions (Critical Risk #27). This research helped NASA improve crew training programs and support services the Agency provides to crews during missions. Dr. Peggy Whitson's "Renal Stone Risk During Space Flight: Assessment and Countermeasure Validation" experiment is testing the use of potassium citrate to combat astronauts' increased risk of renal stones due to bone loss and reduced fluid volume in the body during flight, resulting in higher amounts of calcium in urine (Critical Risk #4). Dr. Peter Cavanagh's "Foot Reaction Forces During Space Flight" experiment examines the bone and muscle loss that occur when the body does not bear weight and the degree to which in-flight exercise, NASA's primary

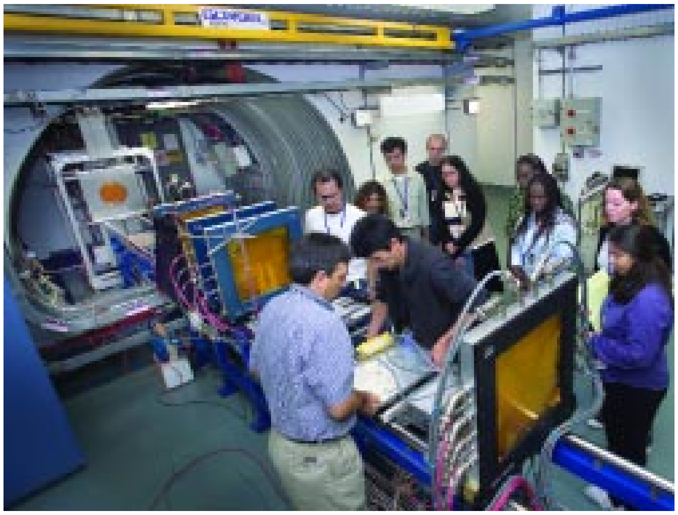
Figure 1345: Astronaut C. Michael Foale (center) and cosmonaut Alexander Y. Kaleri (right) receive training for the Advanced Diagnostic Ultrasound in Microgravity experiment from instructor Ashot Sargsyan on August 18, 2003, in preparation for their participation in International Space Station Expedition 8.

countermeasure for this problem, helps reduce these losses (Critical Risks #20 and #22). Although scientists have conducted a great deal of research on bone loss and muscle atrophy during space flight, "Foot" is the first experiment to quantify the amount of load placed on limbs in microgravity. Dr. Scott Dulchavsky's "Advanced Ultrasonic Diagnosis in Microgravity" experiment tested the use of an ultrasound device onboard the International Space Station to help crewmembers diagnose various medical conditions either on their own or by telemedicine (a process in which a medical professional provides remote assistance using the Internet or radio transmission; Critical Risks #20 and #22). This research will help NASA ensure that crews can care for themselves during long-duration space exploration beyond low Earth orbit. NASA researchers working on Critical Risk #22, which addresses ambulatory care, the diagnosis and management of minor illnesses, management of minor trauma, also published 62 articles and abstracts discussing their findings in FY 2004.

NASA also evaluated the results of biomedical and space medicine research to determine potential applications on Earth. Researchers at the Johnson Space Center recently identified a potential relationship between radiation exposure and cataract formation. This information is beneficial to NASA, as well as to military and civilian aviation medicine. The experiences of those living on the International Space Station helps NASA better understand the effect of space on the human body and the effect of isolation on human behavior and performance. The Station also provides a place to test advanced emergency life-support systems, clinical and surgical capabilities, and astronauts' nutrition requirements as NASA works to meet the Vision for Space Exploration.

Outcome 9.1.2: By 2008, reduce uncertainties in estimating radiation risks by one-half.

Sixty-eight principal investigators used NASA's Space Radiation Laboratory at Brookhaven National Laboratory, one of the few places in the world that can simulate the harsh cosmic and solar radiation environment found in space. This achievement exceeded the annual performance goal of 50 investigators by 18, or 36 percent. NASA also held multiple workshops in FY 2004, including the Third International Workshop on Space Radiation Research, held May 15–20, 2004. And, NASA completed two NASA Space Radiation Laboratory runs in FY 2004: one in the fall and one in the spring, in addition to the commissioning run. The NASA Space Radiation Laboratory became operational in October 2003. Actual research beam use totaled 838 hours in the first contract year exceeding the projected 650 hours for FY 2004 by 188 hours, or 29 percent. NASA continues to study cataract risks through research that evaluates astronaut radiation exposure.



Credit: Brookhaven National Laboratory

Figure 135: Students stand in the target area at the NASA Space Radiation Laboratory.

Outcome 9.1.3: Advance understanding of the role of gravity in biological processes to support biomedical research. NASA made satisfactory progress towards achieving this Outcome by soliciting help from the greater research community in a variety of disciplines. Examples of these solicitations include: "Research Opportunities Soliciting Ground Based Studies for Human Health in Space" and "NASA Research Announcement for Flight Experiments in Space Life Sciences." NASA launched the "Yeast Gap" experiment on a Progress in January 2004, and astronauts on-board the International Space Station conducted related experiment activities in February 2004. NASA also launched the International *C. elegans* Experiment to the International Space Station on May 19, 2004, a collaborative experiment involving the United States, France, Japan, and Canada. Researchers are analyzing the returned data.

Performance Measures for Objective 9.1		2004 Rating	Past Years' Performance Measures and Ratings	2003	2002	2001
Outcome 9.1.1	By 2008, develop and test candidate countermeasures using ground-based analysis and space flight.	green		Outcomes originated in FY 2004		
APG 4BSR8	Use ground-based and space-based research to lessen the risks related to long duration phenomena such as bone loss, physiological adaptation to isolation and confinement, and the biological effects of radiation as described in the Bioastronautics Critical Path Roadmap.	green		3B1 green	2B1 green	none
APG 4BSR9	Publish results of Bioastronautics experiments conducted during early ISS Increments (1 through 8) and preliminary results from Increments 9 and 10.	green		none	none	none
APG 4BSR10	Maintain productive peer-reviewed research program in Biomedical Research and Countermeasures, including a National Space Biomedical Research Institute that will perform team-based focused countermeasure-development research.	green		none	none	none
APG 4SFS10	Certify the medical fitness of all crew members before launch.	green		none	none	none
Outcome 9.1.2	By 2008, reduce uncertainties in estimating radiation risks by one-half.	blue		Outcomes originated in FY 2004		
APG 4BSR11	Expand the space radiation research science community to involve cutting edge researchers in related disciplines by soliciting, selecting, and funding high quality research.	green		none	none	none
APG 4BSR12	Complete two experimental campaigns ("runs") using recently completed National Space Radiation Laboratory (NSRL) at Brookhaven National Laboratory (BNL) to measure survival, genetic mutation (mutagenesis), and chromosome aberrations in cells and tissues to improve understanding of the biological effects of the space radiation environment.	green		none	none	none
APG 4BSR13	Evaluate radiation risks to astronauts by continued and careful analysis of past radiation exposures, results of medical follow up, and comparison with appropriately chosen control population not exposed to similar levels of radiation. Make experimental data available for operational use on ISS and other space-realted activities where appropriate.	green		none	none	none
Outcome 9.1.3	Advance understanding of the role of gravity in biological processes to support biomedical research.	green		Outcomes originated in FY 2004		
APG 4BSR14	Openly solicit ground-based research in appropriate Fundamental Biology disciplines to lay the ground work for advanced understanding of the role of gravity in biological processes associated with the human health risks of space flight.	green		none	none	none
APG 4BSR15	Plan for increased early utilization for basic biology research in 2005 to take advantage of evolving ISS capabilities.	green		none	none	none
APG 4BSR16	Maintain a competitive, productive peer-reviewed research program to advance understanding of the role of gravity in biological processes.	green		none	none	none

Goal 9
Extend the duration and boundaries of human space flight to create new opportunities for exploration and discovery.

OBJECTIVE 9.2

Develop new human support systems and solutions to low gravity technological challenges to allow the next generation of explorers to go beyond low Earth orbit.

WHY PURSUE OBJECTIVE 9.2?

As humans embark on missions of greater duration and distance, NASA must extend its current technological capabilities to achieve greater autonomy, efficiency, reliability, and safety and security in low-gravity environments. This includes enhancing life support systems to maintain an environment and resources—air, water, food, thermal heat, and energy—that will sustain and protect human health and safety during all phases of a mission, including utilizing available resources efficiently at their destination.

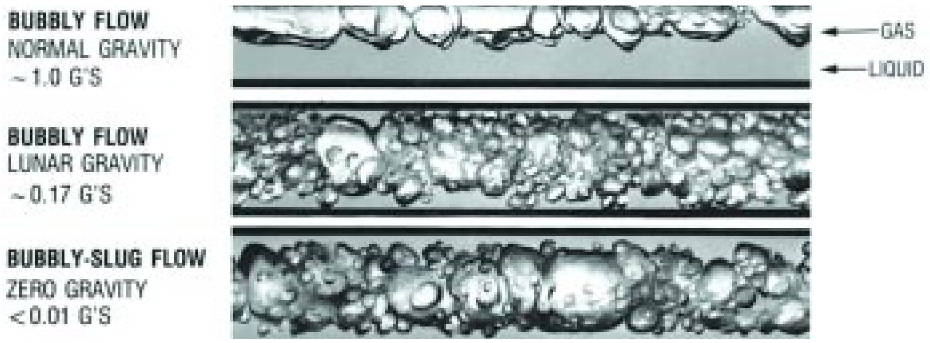


Figure 136: The flow of gas and liquid mixtures, such as steam and water, is strongly affected by gravity. In this picture air–water mixtures are shown at the same flow rates under different gravity levels. NASA researchers must study the phenomena that affect air–water mixtures before engineers can design devices, such as heating or water filtration systems, for use in space.

NASA uses laboratories, analog environments like undersea habitat training facilities, and simulators to develop, test, and verify technologies for advanced space missions. NASA's partners from universities, the private sector, and other government agencies contribute to all phases of research and technology development, including the initial development of concepts, prototype development and testing, fabrication, and final verification. NASA also uses a number of facilities to flight validate technologies, including parabolic flight facilities like the KC-135, drop towers, free flyers, and most important, the International Space Station.

NASA'S PROGRESS AND ACHIEVEMENTS IN FY 2004

Outcome 9.2.1: Identify and test technologies by 2010 to reduce total mass requirements by a factor of three for Life Support using current ISS mass requirement baseline.

NASA made satisfactory progress toward this Outcome during FY 2004. Since 1999, NASA has tracked an advanced life-support metric, and the Agency has achieved a 50-percent reduction in the estimated mass of a life-support system using current technologies compared to the Station's system baselines. The FY 2004 advanced life-support metric showed a moderate increase over FY 2003. First, the dry food mass from both numerator and denominator in the metric calculation was deleted, since the amount of dry food humans need is a fixed quantity. Second, NASA made systems engineering improvements in atmosphere air storage by using cryogenic storage instead of the high-pressure tanks used in the past. Another technology that helped raise the metric is the Vapor Phase Catalytic Ammonia Removal system that represents the next generation in space flight water recovery systems. NASA's Mobile Intelligent Vehicle Health Management System, also known as the Personal Satellite Assistant, provides additional eyes, ears, and other sensory input for astronauts performing internal tasks. The system testbed is now complete, and NASA completed a demonstration of its capability at the end of September.

Outcome 9.2.2: By 2008, develop predictive models for prototype two-phase flow and phase change heat transfer systems for low- and fractional gravity with an efficiency improvement of at least a factor of two over 2003 ISS radiative systems, and prepare ISS experiments for validation.
NASA conducted two major studies to organize research content in multiphase fluid and thermal systems. One, on transport issues in human support systems, is documented in a NASA Technical Memorandum. The other, on engineering issues in fluid and thermal systems, was conducted by a group of nationally-recognized experts and resulted in a report that is in final review. This priority area for research support received one-half of the grant awards in the most recent fluid physics NASA Research Announcement, compared with a historical representation of one quarter to one third. International Space Station research payloads are under review, but significant research activity aboard the Station is still in development for this area.

Figure 137: NASA's Personal Satellite Assistant is an autonomous, free-floating robot equipped with sensors to monitor environmental conditions inside a spacecraft or other enclosed environment.

Outcome 9.2.3: By 2008, develop predictive engineering model and prototype systems to demonstrate the feasibility of deploying enhanced space radiation-shielding multi-functional structures with at least a factor of two improvement in shielding efficiency and mass reduction, and prepare a space experiment for validation.
The NASA Space Radiation Laboratory opened in October 2003 and is now fully operational. Acquisition of data on shielding material performance is now underway. NASA held a workshop in June 2004 to define requirements for Antarctic balloon-borne research on material interactions with energetic solar particles for the Deep Space Testbed project. The report recommended mission content and timelines. NASA released a NASA Research Announcement, including a call for proposals in radiation materials research, in late FY 2004. Budget uncertainties affected selection decisions, but they are expected shortly.

Performance Measures for Objective 9.2		2004 Rating	Past Years' Performance Measures and Ratings	2003	2002	2001
Outcome 9.2.1	Identify and test technologies by 2010 to reduce total mass requirements by a factor of three for Life Support using current ISS mass requirement baseline.	green		Outcomes originated in FY 2004		
APG 4BSR17	Demonstrate, through vigorous research and technology development, a 50% reduction in the projected mass of a life support flight system compared to the system baselined for ISS.	green		3B2 green	2B2 green	none
APG 4HRT14	Demonstrate ground test of a Mobile Intelligent Vehicle Health Management (IVHM) system for internal spacecraft operations that will provide environmental sensing capabilities and knowledge management services. The Mobile IVHM will perform independent calibration checks for environmental sensors; autonomously replace or substitute for failed environmental sensors; hunt down and isolate gas leaks and temperature problems; and provide a range of crew personal data assistant functions.	green		none	none	none
Outcome 9.2.2	By 2008, develop predictive models for prototype two-phase flow and phase change heat transfer systems for low and fractional gravity with an efficiency improvement of at least a factor of two over 2003 ISS radiative systems, and prepare ISS experiments for validation.	blue		Outcomes originated in FY 2004		
APG 4PSR8	Increase the current strategic ground research in microgravity heat exchange and advance the existing ISS investigations toward flight.	green		none	none	none
Outcome 9.2.3	By 2008, develop predictive engineering model and prototype systems to demonstrate the feasibility of deploying enhanced space radiation-shielding multi-functional structures with at least a factor of two improvements in shielding efficiency and mass reduction, and prepare a space experiment for validation.	green		Outcomes originated in FY 2004		
APG 4PSR9	Extend the available database on radiation effects on materials properties using the newly commissioned NASA Space Radiation Laboratory at Brookhaven.	green		none	none	none

Goal 9
Extend the duration and boundaries of human space flight to create new opportunities for exploration and discovery.

OBJECTIVE 9.3

Demonstrate the ability to support a permanent human presence in low Earth orbit as a stepping-stone to human presence beyond.

WHY PURSUE OBJECTIVE 9.3?

Before humans venture beyond the relative safety of low Earth orbit, NASA must be certain that crews are fully prepared. NASA's primary challenge is to move from largely open life support systems that require frequent resupply to closed systems that recycle air, water, and waste. Advanced life-support systems and subsystems must be developed based on a thorough understanding of the underlying biological and physical processes involved. The advanced systems must require less power, be highly reliable and autonomous, and be smaller and lighter than current systems.

Figure 138: With tools in hand, Expedition 8 Flight Engineer Alexander Y. Kaleri and Expedition 7 Flight Engineer and Science Officer Edward T. Lu pause from their work in the Station's Unity Node on October 26, 2003. There has been crew continuously aboard the Station since November 2000, gaining experience of how to live and work in space for extended periods of time.

The International Space Station is serving as the first step to long-duration human space exploration beyond low Earth orbit. The Station is being used to develop life support technologies and create better understanding of the effects of variable gravity and radiation on humans and systems. The Station also provides a platform on which to demonstrate important skills, and their supporting technologies, like in-space construction and manufacturing and autonomous health care. NASA will use the International Space Station to ensure that crews can remain safe and productive with little or no direct support from Earth.

NASA'S PROGRESS AND ACHIEVEMENTS IN FY 2004

Outcome 9.3.1: Develop experience in working and living in space by continuously supporting a crew on-board the ISS through 2016.

The International Space Station has been continuously crewed since November 2000 starting with Expedition 1. At the end of FY 2004, Expedition 9 was onboard the Station, and Expedition 10 arrived safely in October 2004. The Station is on the critical path to fulfilling the Vision for Space Exploration, serving as a testbed for technology demonstration and research in long-duration space exploration.

Performance Measures for Objective 9.3		2004 Rating		2003	2002	2001
Outcome 9.3.1	Develop experience in working and living in space by continuously supporting a crew on-board the ISS through 2016.	green		Outcomes originated in FY 2004		
APG 4ISS6	Continuously sustain a crew to conduct research aboard the ISS.	green		none	none	none

Goal 9 Extend the duration and boundaries of human space flight to create new opportunities for exploration and discovery.

OBJECTIVE 9.4

Develop technologies to enable safe, affordable, effective and sustainable human-robotic exploration and discovery beyond low Earth orbit (LEO).

WHY PURSUE OBJECTIVE 9.4?

Future exploration missions beyond low Earth orbit will require coordinating the unique capabilities of humans and robots to maximize safety, affordability, effectiveness, and sustainability. Robotic explorers will be the trailblazers, gaining insight and critical information about new environments to reduce risk for human explorers. They also will work alongside human explorers, offering an extra set of "hands," performing potentially hazardous tasks, and providing sensors and capabilities beyond what humans can do on their own.

Figure 139: Astronaut Nancy Currie participates in a test with the Robonaut to evaluate human–robotic operations. The Robonaut is just one example of the types of robotic systems that will work alongside human explorers during future space missions.

Through directed investments and innovative partnerships, NASA is developing, maturing, and validating key technologies for human–robotic exploration, including sensor technologies, modular systems, computing capabilities, space communications and networking, and new power and propulsion systems that can be integrated into future missions. NASA also is establishing research and development requirements and roadmaps to help the Agency identify promising technologies and concepts and develop improved technologies for risk analysis to ensure mission success.

NASA'S PROGRESS AND ACHIEVEMENTS IN FY 2004

Outcome 9.4.1: Identify, develop, and validate human-robotic capabilities by 2015 required to support human-robotic lunar missions.

As part of the Vision for Space Exploration, NASA is researching capabilities for human–robotic lunar missions. In support of this activity, NASA published the *Human and Robotic Technology Formulation Plan* on July 29, 2004. The Plan provides the strategy, objectives, and key technical challenges for guiding exploration technology development. Technology development projects will be selected competitively in a strategy-to-task process governed by the Plan. NASA also approved a charter for the Operational Advisory Group of technologists and operators to prepare for the missions. And, NASA created a review process and integration team to select and award intramural and extramural Human and Robotic Technology awards; the Agency selected 50 intramural projects on August 1, 2004. NASA also issued a Broad Agency Announcement on

July 28, 2004, and evaluated over 3,700 notices of intent. Of the 498 full proposals invited, NASA will select about 100 proposals in November 2004.

Outcome 9.4.2: Identify and execute a research and development program to develop technologies by 2015 critical to support human-robotic lunar missions.
NASA held a pre-solicitation conference in June 2004 to familiarize industry with the requirements and process for the NASA Broad Agency Announcement in the area of Human and Robotic Technology. NASA also held a pre-proposal conference in July 2004 for the Human and Robotic Technology Systems-of-Systems Broad Agency Announcement initiating the extramural process.

Outcome 9.4.3: By 2016, develop and demonstrate in space nuclear fission-based power and propulsion systems that can be integrated into future human and robotic exploration missions.
NASA's Project Prometheus is developing the technologies needed to enable expanded exploration via nuclear fission-based power and propulsion systems. The Prometheus team (NASA and the Department of Energy) worked this year to align activities and exploration priorities set forth in the Vision for Space Exploration. This process began with the development of the Jupiter Icy Moons Orbiter Level-1 requirements and is now transitioning into the evaluation of nuclear propulsion and vehicle systems technology roadmaps. Prometheus personnel initiated multi-center, multi-agency focused technology and systems development processes in support of future human and robotic exploration missions.

Outcome 9.4.4: Develop and deliver one new critical technology every two years in at least each of the following disciplines: in-space computing, space communications and networking, sensor technology, modular systems, and engineering risk analysis.
NASA developed the *Human and Robotic Technology Formulation Plan* to establish the spiral technology development process that will lead to the development and delivery of critical technologies required for the development of Exploration Systems. Per the plan's process, NASA held a pre-proposal conference for the Human and Robotic Technology Systems-of-Systems Broad Agency Announcement initiating the extramural process. The Broad Agency Announcement process solicits technology development proposals and will select the most promising technology development activities for the aforementioned disciplines. Upon selection, projects will be established with required funding to develop the critical technologies.

Performance Measures for Objective 9.4		2004 Rating	Past Years' Performance Measures and Ratings	2003	2002	2001
Outcome 9.4.1	Identify, develop, and validate human-robotic capabilities by 2015 required to support human-robotic lunar missions.	green		Outcomes originated in FY 2004		
APG 4HRT1	Formulate guidelines for a top-down strategy-to-task (STT) technology R&D planning process that will facilitate the development of human-robotic exploration systems requirement.	green		none	none	none
APG 4HRT2	Charter an Operational Advisory Group of technologists and operators to prepare for two systems-focused Quality Function Deployment (QFD) exercises that will take place in FY 2005.	green		none	none	none
APG 4HRT3	Charter a Technology Transition Team that will review candidate human-robotic exploration systems technologies, and provide detailed updates to human-robotic technology road maps.	green		none	none	none
Outcome 9.4.2	Identify and execute a research and development program to develop technologies by 2015 critical to support human-robotic lunar missions.	green		Outcomes originated in FY 2004		
APG 4HRT4	Conduct an "Industry Day" by mid-FY 2004 to communicate the Exploration Systems Enterprise vision and processes.	green		none	none	none
Outcome 9.4.3	By 2016, develop and demonstrate in space nuclear fission-based power and propulsion systems that can be integrated into future human and robotic exploration missions.	green		Outcomes originated in FY 2004		
APG 4HRT5	Review nuclear propulsion and vehicle systems technology roadmap for alignment with exploration priorities, particularly human-related system and safety requirements.	green		none	none	none
Outcome 9.4.4	Develop and deliver 1 new critical technology every 2 years in at least each of the following disciplines: in-space computing, space communications and networking, sensor technology, modular systems, and engineering risk analysis.	green		Outcomes originated in FY 2004		

Goal 9
Extend the duration and boundaries of human space flight to create new opportunities for exploration and discovery.

OBJECTIVE 9.5
Develop crew transportation systems to enable exploration beyond low Earth orbit (LEO).

WHY PURSUE OBJECTIVE 9.5?

Current space transportation is inadequate for human space exploration beyond low Earth orbit. Future space vehicles need improved power and propulsion, better radiation protection, lighter materials, and increased mission flexibility. The Space Shuttle was designed primarily as a reusable vehicle to transport crews and small payloads that could be assembled into large systems in space, like the International Space Station.

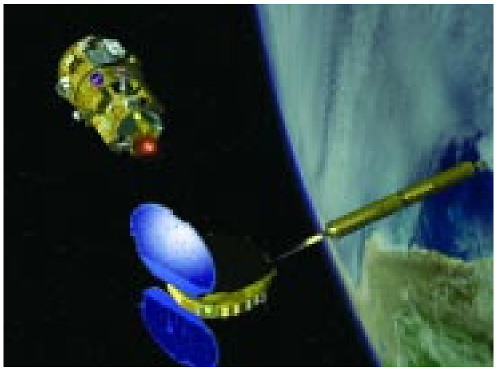


Figure 140: The Demonstration of Autonomous Rendezvous Technology (DART), shown here in an artist's concept rendezvousing with a target satellite, will develop and demonstrate key technologies for an autonomous approach to the International Space Station. DART is one of the building blocks for developing new crew transportation systems.

NASA has extended this modular "building block" approach as the conceptual foundation for creating the next generation of space transportation capabilities. The Agency is developing new crew transportation systems using an incremental approach that begins with an autonomous prototype that can evolve into a crew-rated vehicle. The major goal is to use affordable engineering practices and flexible designs that can be upgraded and altered to meet NASA's needs and take advantage of technology developments. NASA is leveraging its partnerships with other government agencies, industry, and academia to take advantage of advances in materials, power and propulsion, computing, and design. With its partners, NASA is conducting trade studies and other research to determine the best technology investments.

NASA'S PROGRESS AND ACHIEVEMENTS IN FY 2004

Outcome 9.5.1: By 2014, develop and flight-demonstrate a human exploration vehicle that supports safe, affordable and effective transportation and life support for human crews traveling from the Earth to destinations beyond LEO.

NASA made progress on the new Crew Transportation System as part of Project Constellation, a system of human and robotic spacecraft, launch vehicles, and lunar surface infrastructure required to get astronauts to and from the Moon and Mars. NASA is well into the planning process for the Crew Exploration Vehicle, the first element of this system. The Agency completed the acquisition strategy for the procurement of the Crew Exploration Vehicle and its associated launch vehicle. In addition, NASA selected 11 industry teams to work on the concept exploration and refinement effort for the vehicle. NASA continues to direct technology development efforts, which are beginning to bear fruit: the Demonstration of the Autonomous Rendezvous Technology program passed flight certification and is ready for launch from Vandenberg Air Force Base to demonstrate an autonomous rendezvous and docking capability. NASA also reviewed the Orbital Space Plane and Next Generation Launch Technology programs' lessons learned and is integrating these lessons into a risk management database to be used by the Project Constellation team to manage development of the Crew Transportation System.

Outcome 9.5.2: By 2010, identify and develop concepts and requirements that could support safe, affordable, and effective transportation and life support for human crews traveling from the Earth to the vicinity or the surface of Mars.

NASA defined requirements for supporting the safe transportation of humans to the vicinity and surface of Mars using a spiral development approach. The first spiral involves the definition of a Crew Exploration Vehicle for piloted launch in 2014. The second spiral will carry humans to the surface of the Moon and prove the equipment and techniques to be used in the later spirals to Mars. For future reference, NASA captured previous architecture and trade studies related to this effort in the Space Transportation Information Database at Marshall Space Flight Center. NASA also performed and catalogued new trade studies to help formulate requirements for the Crew Exploration Vehicle.

Performance Measures for Objective 9.5		2004 Rating	Past Years' Performance Measures and Ratings	2003	2002	2001
Outcome 9.5.1	By 2014, develop and flight-demonstrate a human exploration vehicle that supports safe, affordable, and effective transportation and life support for human crews traveling from Earth to destinations beyond LEO.	green		Outcomes originated in FY 2004		
APG 4TS1	The Demonstration of Autonomous Rendezvous Technology flight article will be certified for flight demonstration, establishing it as a test platform for demonstrating key technologies required to enable an autonomous (no pilot in the loop) approach to the International Space Station.	green		3SLI3 green	None	none
APG 4TS2	Conduct full reviews of OSP and NGLT programs, identifying acquisitions strategies, technologies, and lessons learned that are applicable to the new CEV program.	green		none	None	none
Outcome 9.5.2	By 2010, identify and develop concepts and requirements that could support safe, affordable, and effective transportation and life support for human crews traveling from the Earth to the vicinity or the surface of Mars.	green		Outcomes originated in FY 2004		
APG 4TS3	Compile a document that catalogs major architecture and engineering trade studies of space transportation architectures for human Mars exploration.	green		none	None	none

Goal 10 Enable revolutionary capabilities through new technology.

OBJECTIVE 10.1

Improve the capability to assess and manage risk in the synthesis of complex engineering systems.

WHY PURSUE OBJECTIVE 10.1?

Safety is one of NASA's core values. The safety of the public, NASA's people, and the Agency's major physical assets are of primary concern when NASA plans any mission or program. But to uphold this value, NASA recognizes that a certain amount of risk is inherent in any complex engineering system. A failure in a single subsystem can cause a cascade effect that may result in a mission not achieving some of its goals or failing completely. The key to mission success and safety is to identify potential failure points and devise ways to manage or avoid them early in mission development.

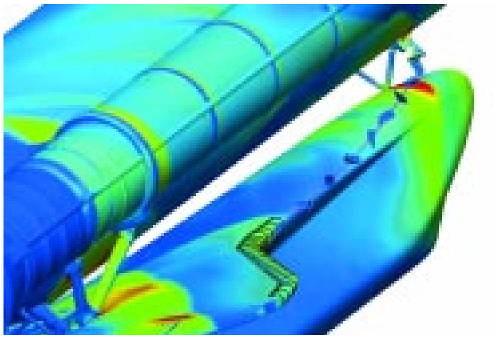


Figure 141: This image shows the computed trajectory (indicated by the pink line) of debris that damaged the wing of *Columbia* shortly after launch and ultimately caused its accident in February 2003. Computer modeling and simulation capabilities such as this can help to both investigate and analyze failures, as well as predict potential failures modes.

NASA is developing software tools that will help technologists and program planners analyze designs and organizational risks in subsystems, systems, and mission architectures. Such tools will allow planners to substitute components, subsystems, and systems and to identify trade-off capabilities between risks, as well as between risks and other mission design criteria. These risk assessment tools also will create a robust knowledge capture and communications process and increase a planner's ability to assess current status and implement successful risk control strategies. NASA also is designing software tools for accident investigation that will help scientists identify the causes of spacecraft, airplane, and other mission hardware accidents. Ultimately, all of NASA's risk assessment tools will allow planners to evaluate risks to humans and missions with the same fidelity and confidence that they now have in assessing standard parameters like cost, schedule, and performance.

NASA'S PROGRESS AND ACHIEVEMENTS IN FY 2004

Outcome 10.1.1: By 2005 demonstrate 2 prototype systems that prove the feasibility of resilient systems to mitigate risks in key NASA mission domains. Feasibility will be demonstrated by reconfigurability of avionics, sensors, and system performance parameters.

NASA developed prototypes of risk analysis tools to integrate capabilities for archiving, searching, visualizing, and investigating hazards. The Risk Tool Suite for Advanced Design aids users in considering a wide range of risk types (e.g., hardware, software, programmatic, organizational). The suite helps designers determine a number of optimal portfolios of project risks, costs, and mitigations, which they can analyze and use to guide them in choosing the best portfolio.

The Mishap and Anomaly Information System provides the capability to evaluate historical mishap and anomaly data for patterns, trends, and associated risks, then integrates this capability with the Risk Tool Suite to better utilize historical data to enhance early-phase design.

Through the fusion of accident investigation methodology with collaborative, information sharing technology, the Investigation Organizer tool has been used for multiple investigations, most recently by the overall Columbia Accident Investigation Board. In addition, the National Transportation Safety Board and other Federal agencies are evaluating this tool for their use, and it is being commercialized through a partnership with Xerox Corporation.

Performance Measures for Objective 10.1		2004 Rating		2003	2002	2001
Outcome 10.1.1	By 2005, demonstrate 2 prototype systems that prove the feasibility of resilient systems to mitigate risks in key NASA mission domains. Feasibility will be demonstrated by reconfigurability of avionics, sensors, and system performance parameters.	green		Outcomes originated in FY 2004		
APG 4HRT7	Develop a Prototype Concept Design Risk Workstation that provides the capability to identify, track, and trade-off risk in the conceptual design phase of missions. The workstation will integrate databases, visualization modules, solicitation routines, system simulations, and analysis programs that support an interactive system design process.	green		3R11 green	none	none

Note: Objective 10.2 was cancelled.

Goal 10 Enable revolutionary capabilities through new technology.

OBJECTIVE 10.3

Leverage partnerships between NASA Enterprises, U.S. industrial firms, and the venture capital community for innovative technology development.

WHY PURSUE OBJECTIVE 10.3?

The ambitious task of safely returning humans to the Moon, and eventually sending human crews to Mars, cannot be accomplished by NASA alone. Achieving these goals will come only as a result of a team effort reflecting uncommon creativity and dedication, so NASA is working closely with other government agencies, industry, and academia partners to identify innovative ideas and pool resources. The Agency also is fostering even greater cooperation among its Mission

Figure 142: NASA will develop exploration technologies, like the vehicle shown in this artist's concept of lunar exploration, in cooperation with many internal and external partners.

Directorates to leverage most fully NASA's extraordinary science and technology competencies. Through directed investments and innovative partnerships, NASA will develop, mature, and validate advanced technologies and space operations concepts. These technologies will form the cornerstone of future exploration capabilities that are safe, affordable, effective, and sustainable.

NASA'S PROGRESS AND ACHIEVEMENTS IN FY 2004

Outcome 10.3.1: Promote and develop innovative technology partnerships between NASA, venture capital firms, and U.S. industry for the benefit of all Enterprise mission needs, initiating three partnerships per year.

In FY 2004, NASA signed 62 partnership agreements with industry. These agreements allow technology from outside NASA to be incorporated into NASA programs. NASA also made progress in the Agency's Enterprise Engine program. The Enterprise Engine will be managed according to commercial investment principles. To date, the partners have met with nearly 40 representatives from the venture and corporate venture communities, and they made presentations and/or served as panel members at relevant industry conventions. These activities generated significant interest and potential investment opportunities. In addition, the partnership team is in the process of hiring a law firm to assist in the establishment of a non-profit organization to act as NASA's agent for investment transactions—an identical operating model deployed by the Central Intelligence Agency with their In-Q-Tel venture capital arm. This new organization and its board of trustees should be in place by the start of 2005.

Outcome 10.3.2: Facilitate on an annual basis the award of venture capital funds or Phase III contracts to no less than two SBIR firms to further develop or produce their technology through industry or government agencies.

The NASA Alliance for Small Business Opportunity awarded venture capital funds to two firms: WaveBand Corporation and Tao of Systems Integration, Inc. WaveBand Corporation needed a flight test to validate product claims for prospective customers. The NASA Alliance team confirmed the commercialization potential of its autonomous landing radar system technology then shared the costs of a flight test with WaveBand. WaveBand now is competing on millions of dollars of contracts and has attracted private equity investment. The NASA Alliance also provided $30,000 to supplement WaveBand's funding of $70,000, to collect data through flight testing on a Cessna.

Tao of Systems Integration, Inc. invested ten years in the development of its robust flow characterization technology platform. The NASA Alliance team reviewed the commercialization potential then partnered with Tao to plan and execute a strategy. The team considered and ranked initial applications, adopted a marketing strategy, developed a business model, prepared a sequence of presentations, and made introductions to potential partners. Today, Tao is being considered for a licensing agreement, and Tao received a $60,000 contract from NASA's Dryden Flight Research Center to flight test a sensor. In addition, the Jet Propulsion Laboratory is testing one of Tao's instruments.

Performance Measures for Objective 10.3		2004 Rating	Past Years' Performance Measures and Ratings	2003	2002	2001
Outcome 10.3.1	Promote and develop innovative technology partnerships between NASA, venture capital firms and U.S. industry for the benefit of all Enterprise mission needs, initiating three (3) partnerships per year.	blue		Outcomes originated in FY 2004		
APG 4HRT8	Establish 3 partnerships with U.S. industry and the investment community using the Enterprise Engine concept.	yellow		none	none	none
APG 4HRT9	Develop 36 industry partnerships that will add value to NASA Enterprises.	blue		none	none	none
Outcome 10.3.2	Facilitate on an annual basis the award of venture capital funds or Phase III contracts to no less than two (2) SBIR firms to further develop or produce their technology through industry or government agencies.	green		Outcomes originated in FY 2004		
APG 4HRT10	Achieve through NASBO, the award of Phase III contracts or venture capital funds to 2 SBIR firms to further develop or produce their technology through industry or government agencies.	green		none	none	none

Note: See NASA's Performance Improvement Plan at the end of Part 2 for details on FY 2004 APGs and Outcomes rated Red, Yellow, or White.

Note: Objective 10.4 was cancelled.

Goal 10 Enable revolutionary capabilities through new technology.

OBJECTIVE 10.5

Create novel aeronautics concepts and technology to support science missions and terrestrial and space applications.

WHY PURSUE OBJECTIVE 10.5?

NASA uses its unique capabilities to develop advanced concepts and technologies that are critical to the future of aeronautics. Among these technologies are those for autonomous flight, especially at very high altitudes and for very long durations. NASA is partnered with the Federal Aviation Administration, the Department of Defense, and industry to guide uncrewed aerial vehicle development. The partnerships' goal is to enable routine, long-endurance operation in the national airspace above 18,000 feet.

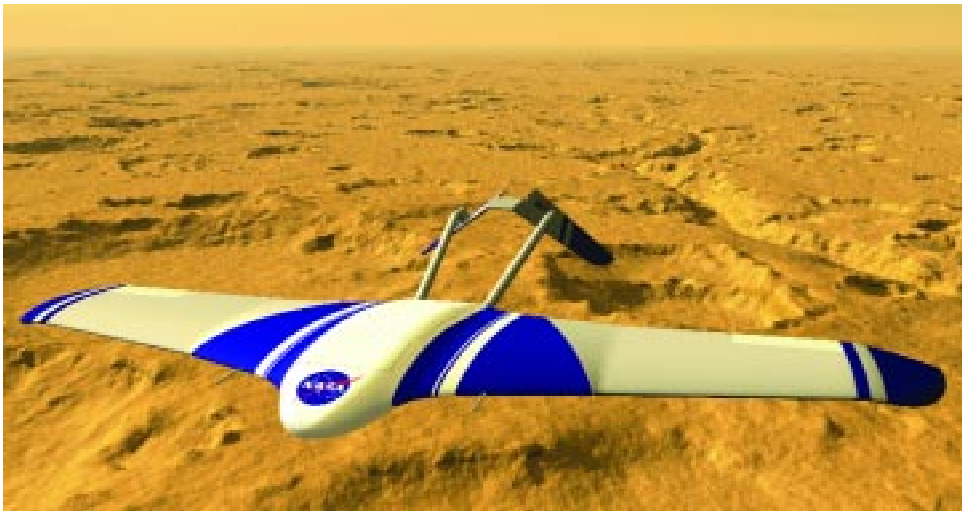


Figure 143: NASA develops winged flight vehicles, like this Mars flyer concept, that can operate in different and unique atmospheres.

NASA also is examining the application of aeronautical technologies to the atmospheres of other planets to design and create the mobile exploration vehicles of the future. NASA's major areas of technology research and development are: ultra-light, smart materials and structures to reduce aircraft weight; new energy sources like solar-powered fuel cells; intelligent power management systems; and autonomous control systems.

NASA'S PROGRESS AND ACHIEVEMENTS IN FY 2004

Outcome 10.5.1: Develop technologies that will enable solar powered vehicles to serve as sub-orbital satellites for science missions.

As a result of the loss of the Helios prototype uncrewed aerial vehicle in June 2003, NASA reexamined the Agency's approach to developing technology for uncrewed aerial vehicles as sub-orbital platforms and cancelled APG 4AT18. The Helios prototype used energy derived from the Sun by day and from fuel cells at night. It was designed as the forerunner of high-altitude, uncrewed aerial vehicles that can fly ultra-long duration environmental science or telecommunications relay missions without using consumable fuels or emitting airborne pollutants. New plans call for NASA to test a regenerative fuel cell in an altitude chamber in FY 2009 to meet refined flight objectives for High Altitude Long Endurance.

Credit: NASA/T. Tschida

Figure 144: The Federal Aviation Administration has granted routine access to the National Airspace System (NAS) to high-altitude, long-endurance, remotely operated aircraft like the Altair Predator B, shown here taking to the air in its first check-out flight in June 2003. Access to the NAS was a critical step in utilizing the full capabilities of remotely operated aircraft.

Outcome 10.5.2: By 2008, develop and demonstrate technologies required for routine Unmanned Aerial Vehicle operations in the National Airspace System above 18,000 feet for High-Altitude, Long-Endurance (HALE) UAVs.

NASA made progress toward this Outcome by working with the Federal Aviation Administration on an agreement and recommendations for allowing High Altitude Long Endurance Remotely Operated Aircraft to operate in the National Airspace System. NASA achieved agreement on the portfolio of technologies and associated performance metrics that, if achieved, will allow routine operation of uncrewed aerial vehicles in the national airspace at Flight Level 400 or 40,000 feet (above where most planes fly). These technologies are being developed and will be demonstrated in actual flight tests. The results of these tests then will be provided to an external advisory committee, as required by law, prior to the Federal Aviation Administration issuing new policy or rules. Once vetted through the committee, the Federal Aviation Administration can issue new rules, policy, and directives required to enable routine, safe, and secure High Altitude Long Endurance Remotely Operated Aircraft access to the National Airspace System above Flight Level 400.

Performance Measures for Objective 10.5		2004 Rating	Past Years' Performance Measures and Ratings	2003	2002	2001
Outcome 10.5.1	Develop technologies that will enable solar powered vehicles to serve as sub-orbital satellites for science missions.	green		Outcomes originated in FY 2004		
APG 4AT18	Demonstrate the efficient performance of a flight-prototype regenerative energy storage system in an altitude chamber.	red		none	none	none
Outcome 10.5.2	By 2008, develop and demonstrate technologies required for routine Unmanned Aerial Vehicle operations in the National Airspace System above 18,000 feet for High-Altitude, Long-Endurance (HALE) UAVs.	green		Outcomes originated in FY 2004		
APG 4AT15	Deliver a validated set of requirements for UAV access at and above FL400, and a preliminary set of requirements for access at and above FL180.	green		none	none	none

Note: See NASA's Performance Improvement Plan at the end of Part 2 for details on FY 2004 APGs and Outcomes rated Red, Yellow, or White.

Implementing Strategies to Conduct Well-Managed Programs

WHAT ARE IMPLEMENTING STRATEGIES AND WHY PURSUE THEM?

In addition to tracking and reporting performance on 10 Strategic Goals, NASA also monitors and reports on the Agency's performance in a number of management goals called Implementing Strategies. These strategies are not unique to NASA. They are organizational efficiency measures similar in purpose to the sound planning and management principles, practices, and strategies of all well-run organizations, and they are critical to NASA's achievement of the Agency's Strategic Goals, Objectives, Performance Outcomes, and APGs.

NASA's Implementing Strategy APGs are organized according to the Agency's 18 Budget Themes (e.g., Solar System Exploration, Mars Exploration Program, Astronomical Search for Origins) to emphasize individual program area accountability.

NASA'S PROGRESS AND ACHIEVEMENTS IN FY 2004

NASA's progress in the Agency's Implementing Strategy areas is documented in the following table. The NASA Performance Improvement Plan includes explanations for Implementing Strategy APGs that were rated Yellow, Red, or White. Performance trend information is unavailable for Implementing Strategy APGs since Implementing Strategies are new performance measures introduced in FY 2004.

Performance Measures for Implementing Strategies		2004 Rating	Comments
Solar System Exploration			
APG 4SSE1	Complete all development projects within 110% of the cost and schedule baseline.	yellow	The Solar System Exploration Theme successfully launched the MESSENGER mission to Mercury on August 3, 2004. MESSENGER was developed, completed, and launched within 110% of the schedule baseline, but exceeded the cost baseline established at the Mission Confirmation Review by 16.5%. This resulted in a Yellow rating on cost (4SSE1) and a Green rating on schedule (4SSE3).
APG 4SSE2	Each research project will allocate 75% of its funding competitively during FY 2004.	green	The Solar System Exploration Theme allocated 93% of its research funding competitively in FY 2004.
APG 4SSE3	SSE will complete all of its missions within 10% of their baseline schedules.	green	The Solar System Exploration Theme successfully launched the MESSENGER mission to Mercury on August 3, 2004. The MESSENGER mission was developed, completed, and launched within 110% of the schedule baseline, but exceeded the cost baseline established at the Mission Confirmation Review by 16.5%. This resulted in a Yellow rating on cost (4SSE1) and a Green rating on schedule (4SSE3).
Accomplish key development activities in support of Solar System Exploration			
APG 4SSE4	Successfully launch MESSENGER.	green	The Solar System Exploration Theme successfully launched the MESSENGER mission to Mercury on August 3, 2004.
APG 4SSE5	Deliver the Deep Impact spacecraft for Environmental Testing.	green	The Deep Impact spacecraft successfully completed environmental testing and is scheduled for launch in December 2004.
APG 4SSE6	Successfully complete the New Horizons/Pluto Critical Design Review (CDR).	green	The New Horizons/Pluto Critical Design Review was successfully completed in October 2003.
Accomplish key technology activities in support of Solar System Exploration			
APG 4SSE7	Define the Level One science goals for the Jupiter Icy Moons Orbiter (JIMO) Mission.	yellow	The JIMO Science Definition Team recommended goals, and NASA senior management plans to make final determination by mid-FY 2005.
APG 4SSE8	Release an NRA for high capability instruments useful on the JIMO Mission and follow-on Project Prometheus payloads.	green	The NASA Research Announcement for high-capability instruments for planetary exploration was released on July 23, 2003, ahead of schedule.
APG 4SSE9	Release an NRA for the next New Frontiers Mission.	green	The Announcement of Opportunity for the next New Frontiers mission was released on October 10, 2003.

Performance Measures for Implementing Strategies		2004 Rating	Comments
Mars Exploration Program			
APG 4MEP1	Complete all development projects within 110% of the cost and schedule baseline.	white	The Theme did not have any missions scheduled for development completion in FY 2004.
APG 4MEP2	Each research project will allocate 75% of its funding competitively during FY 2004.	green	The Mars Exploration Program Theme allocated 92% of its research funding competitively in FY 2004.
APG 4MEP3	MEP will complete all of its missions within 10% of their baseline schedules.	white	The Theme did not have any missions scheduled for development completion in FY 2004.
Accomplish key development activities in support of Mars Exploration			
APG 4MEP4	Successfully land at least one of the two Mars Exploration Rovers.	green	The twin Mars Exploration Rovers landed successfully on the surface of Mars; *Spirit* on January 3 in Gusev Crater and *Opportunity* on January 25 in the Meridiani Planum.
APG 4MEP5	Successfully complete the Level One Requirements for the Mars Exploration Rover Mission.	green	The Mars Exploration Rovers *Spirit* and *Opportunity* completed the mission's Level One requirements with astonishing success, and are currently in an extended operations phase, having lasted far beyond the anticipated operational timeframe.
APG 4MEP6	Successfully complete the 2005 Mars Reconnaissance Orbiter (MRO) Assembly, Test, and Launch Operations (ATLO) Readiness Review.	green	Successful completion of the 2005 Mars Reconnaissance Orbiter Assembly, Test, and Launch Operations Readiness Review occurred in March 2004.
Accomplish key technology activities in support of Mars Exploration			
APG 4MEP7	Complete Laser Communication Demonstration Concept Review.	green	NASA completed the Laser Communication Demonstration Concept Review in January 2004.
APG 4MEP8	Release Instrument Announcement of Opportunity (AO) for the 2009 Mars Science Laboratory (MSL).	green	NASA released the 2009 Mars Science Laboratory Instrument Announcement of Opportunity on April 14, 2004.
Astronomical Search for Origins			
APG 4ASO1	Complete all development projects within 110% of the cost and schedule baseline.	white	The Theme did not have any missions scheduled for development completion in FY 2004.
APG 4ASO2	Each research project will allocate 75% of its funding competitively during FY 2004.	green	The Astronomical Search for Origins Theme allocated 99% of its research funding competitively in FY 2004.
APG 4ASO3	ASO will complete all of its missions within 10% of their baseline schedules.	white	The Theme did not have any missions scheduled for development completion in FY 2004.
Accomplish key development activities in support of the Astronomical Search for Origins			
APG 4ASO4	Successfully complete Hubble Space Telescope (HST) Cosmic Origins Spectrograph (COS) development.	green	NASA successfully completed development of the Hubble Space Telescope Cosmic Origins Spectrograph.
APG 4ASO5	Successfully complete Stratospheric Observatory For Infrared Astronomy (SOFIA) Observatory Flight Test.	yellow	The Stratospheric Observatory For Infrared Astronomy Observatory flight test was not completed due to problems encountered with aerospace vendors and telescope installation. NASA overcame these problems, and the flight test is scheduled for FY 2005.
APG 4ASO6	Successfully complete Space Infrared Telescope Facility (SIRTF) In-Orbit Checkout (IOC) and Science Verification.	green	The Spitzer Space Telescope (formerly called the Space Infrared Telescope Facility), launched in August 2003, successfully completed its in-orbit checkout and science verification and is returning spectacular images from regions of space that are hidden from optical telescopes.
Accomplish key technology activities in support of the Astronomical Search for Origins			
APG 4ASO7	Establish and freeze James Webb Space Telescope (JWST) System-Level Requirements.	green	The James Webb Space Telescope System-Level Requirements were established and frozen with the completion of the mission System Requirements Review in December 2003.
APG 4ASO8	Validate Microarcsecond Metrology (MAM-1) Testbed progress toward interferometer sensor performance for Space Interferometry Mission (SIM).	green	NASA validated Microarcsecond Metrolog Testbed progress toward interferometer sensor performance for the Space Interferometry Mission with the completion of Technology Gate Seven in July 2004.
Structure and Evolution of the Universe			
APG 4SEU1	Complete all development projects within 110% of the cost and schedule baseline.	red	NASA successfully launched the Gravity Probe B mission in April 2004. However, development and launch of the mission far exceeded the cost (by 37%) and schedule baselines established at the Mission Confirmation Review due to unprecedented technical challenges.
APG 4SEU2	Each research project will allocate 75% of its funding competitively during FY 2004.	green	The Structure and Evolution of the Universe Theme allocated 97% of its research funding competitively in FY 2004.
APG 4SEU3	SEU will complete all of its missions within 10% of their baseline schedules.	red	NASA successfully launched the Gravity Probe B mission in April 2004. However, development and launch of the mission far exceeded the cost (by 37%) and schedule baselines established at the Mission Confirmation Review due to unprecedented technical challenges.
Accomplish key development activities to advance understanding of the Structure and Evolution of the Universe:			
APG 4SEU4	Successfully complete the Gamma-ray Large Area Space Telescope (GLAST) Mission Confirmation Design Review (CDR).	green	Successful completion of the Gamma-ray Large Area Space Telescope Mission Confirmation Design Review occurred in September 2004.
APG 4SEU5	Successfully launch Swift.	yellow	Completion and launch of the Swift spacecraft was also scheduled for FY 2004; however, due to technical problems and, more recently, hurricane-related delays, the launch is now scheduled for November 2004. Swift will exceed the schedule threshold and will exceed the cost baseline by approximately 40%.
APG 4SEU6	Successfully complete Pre-Ship Review of Astro-E2 instruments X-ray Spectrometer (XRS) and X-ray Telescope (XRT).	green	Successful completion of the Pre-Ship Reviews of the X-ray Spectrometer and X-ray Telescope was followed by shipment of these instruments to Japan for the Japanese Astro-E2 X-ray astronomy mission.
Accomplish key technology activities to advance understanding of the Structure and Evolution of the Universe:			
APG 4SEU7	Begin Formulation/Phase A for the Laser Interferometer Space Antenna (LISA) Mission.	green	NASA began Formulation/Phase A for the Laser Interferometer Space Antenna Mission with the completion of the Formulation Authorization Document.
APG 4SEU8	Complete Constellation-X (Con-X) design and fabricate the 8x8 Transition Edge Sensor Array for the X-ray Microcalorimeter Spectrometer.	green	NASA completed the design and fabrication of the Constellation-X Transition Edge Sensor Array for the X-ray Microcalorimeter Spectrometer.

Performance Measures for Implementing Strategies		2004 Rating	Comments
Sun-Earth Connection			
APG 4SEC1	Complete all development projects within 110% of the cost and schedule baseline.	white	The Theme did not have any missions scheduled for development completion in FY 2004.
APG 4SEC2	Each research project will allocate 75% of its funding competitively during FY 2004.	green	The Sun-Earth Connection Theme allocated 99% of its research funding competitively in FY 2004.
APG 4SEC3	SEC will complete all of its missions within 10% of their baseline schedules.	white	The Theme did not have any missions scheduled for development completion in FY 2004.
Accomplish key development activities to advance understanding of the Sun-Earth Connection:			
APG 4SEC4	Begin Solar Terrestrial Relations Observatory (STEREO) Integration & Testing (I&T).	yellow	Integration and testing of the Solar Terrestrial Relations Observatory spacecraft was delayed several months due to industry-wide thruster valve problems, and is now scheduled for early FY 2005.
APG 4SEC5	Begin Solar Dynamics Observatory (SDO) Implementation.	green	The Solar Dynamics Observatory mission began implementation in FY 2004 with successful completion of the Mission Confirmation Review.
Accomplish key technology activities to advance understanding of the Sun-Earth Connection:			
APG 4SEC6	Release Announcement of Opportunity (AO) for Geospace Missions.	white	Release of the Announcement of Opportunity for Geospace Missions has been put on hold pending a re-prioritization of missions that will flow from NASA's new Science Mission Directorate strategic plan. It is anticipated that either a Geospace Missions Announcement of Opportunity or, if appropriate, a replacement would be released in FY 2005.
APG 4SEC7	Make AO selections for Magnetospheric Multiscale Mission.	green	NASA selected two Magnetospheric Multiscale Mission proposals for feasibility studies.
Earth System Science			
APG 4ESS1	Complete all development projects within 110% of the cost and schedule baseline.	green	The Earth System Science Theme examined development cost changes for the one project launched in FY 2004, Aura, and the increase in development cost from the initial baseline estimate to the FY 2006 draft budget submit was 10%. The Aura project was within cost and schedule and, therefore, within the measure parameters.
APG 4ESS2	Research: Each research project will allocate 80% of its funding competitively during FY 2004.	green	The Earth System Science Theme allocated 82% of its funding competitively in FY 2004.
APG 4ESS3	Development: Each project will complete its mission within 10% of its baseline schedules.	red	With respect to development, see the Detailed Performance Improvement Plan.
APG 4ESS4	Technology: Successfully develop and infuse technologies that will enable future science measurements by 1) advancing 25% of funded technology developments one Technology Readiness Level, and 2) maturing 2-3 technologies to the point where they can be demonstrated in space or in an operational environment.	green	Development projects were advanced by at least one technology readiness level and three technologies were matured to the point where they can be demonstrated in space or in an operational environment.
APG 4ESS5	Operations: At least 90% of all on-orbit instruments will be operational during their design lifetimes.	green	This Theme has 15 missions currently in operation: eight of them are in Primary Mission phase. The remaining seven are in Extended Mission phase. There are a total of 43 instruments in orbit, with 39 operating. Of those, 20 are in Primary Mission phase and are in operation. One hundred percent of on orbit instruments in Primary Mission phase are operational. The percentage of all on orbit instruments operating (including Extended Mission phase) is 90.7%.
APG 4ESS6	Data information systems and services: Disseminate data that are easy to access to science focus area customers.	green	NASA made an unprecedented volume of data available to researchers in the Earth science research focus areas. Reprocessed data from the Terra and Aqua missions, with improved calibration and science quality, were available online through the Earth Observing System Data and Information System (EOSDIS). The National Quality Research Center at the University of Michigan conducted a customer satisfaction study for NASA, and the results confirmed NASA's success in disseminating data to its customers. The American Customer Satisfaction Index score for EOSDIS was 75, exceeding both the national average for all industries and the national average for Federal agencies. The study results, based on a survey of over 1,000 EOSDIS users, indicated that the users (primarily science researchers) were very satisfied with the products and services provided by EOSDIS and the Distributed Active Archive Centers
Earth Science Applications			
APG 4ESA7	Deliver at least 90% of operating hours for all operations and research facilities.	green	This Theme uses E-Government tools and information system/engineering facilities to execute program activities efficiently. In FY 2004, unplanned downtime for all tools and facilities was less than 1%.
APG 4ESA8	At least 80%, by budget, of research projects will be peer-reviewed and competitively awarded.	green	In addition, this Theme's management uses competitive techniques (open solicitations, competitive contracting, and peer review) to achieve high performance and best value for the program to the greatest extent practical. Of the $100.5 million Theme budget, $75.4 million was available for research projects after institutional costs were subtracted. Of that, over $61 million (81%) of funded projects were implemented using competitive techniques.
Biological Sciences Research			
APG 4BSR18	Complete all development projects within 110% of the cost and schedule baseline.	green	Biological Sciences Research completed the development of the second Human Research Facility and was ready for launch in March 2003. Due to the stand-down of flights after the Columbia accident, this hardware was put on hold until return to flight. Within the downtime, regular maintenance, upgrades, and reviews incurred additional costs above the baseline. Therefore, the second Human Research Facility project was evaluated above the cost and schedule baseline for 2004.
APG 4BSR19	At least 80%, by budget, of research projects will be peer-reviewed and competitively awarded.	green	In FY 2004, 100% of the Bioastronautics Research projects, both intramural and extramural, were peer-reviewed and competitively awarded.

Performance Measures for Implementing Strategies		2004 Rating	Comments
Physical Sciences Research			
APG 4PSR10	Complete all development projects within 110% of the cost and schedule baseline.	green	Issues with the Shuttle and International Space Station programs affected costs associated with Physical Sciences Research flight projects. NASA cut program content to produce better strategic alignment between Agency goals and program objectives. However, the remaining content has shown good cost control within the limits of controllable factors.
APG 4PSR11	At least 80%, by budget, of research projects will be peer-reviewed and competitively awarded.	green	Information on research project awards was not reported.
Research Partnerships and Flight Support			
APG 4RPFS11	Deliver at least 90% of operating hours for all operations and research facilities.	green	NASA's Payload Operations and Integration Center continuously ran the research operations for the International Space Station.
Aeronautics Technology			
APG 4AT1	Complete all development projects within 110% of the cost and schedule baseline.	white	The Aeronautics Theme had no development projects in the FY 2004 Performance Plan.
APG 4AT2	The Theme will allocate 75% of its procurement funding competitively during FY 2004.	green	The Theme obligated in excess of 90% of its procurement funding on competitively awarded contractual vehicles.
APG 4AT3	The Theme will complete 90% of the major milestones planned for FY 2004.	green	The Theme completed 92% of its planned major milestones in FY 2004.
Education			
APG 4ED24	At least 80%, by budget, of research projects will be peer-reviewed and competitively awarded.	green	The majority of NASA's education program opportunities were competitively awarded.
Transportation Systems			
APG 4TS5	The Theme will distribute at least 80% of its allocated procurement funding to competitively awarded contracts.	green	NASA's Constellation Systems team distributed 95% of its allocated procurement funding to competitively awarded contracts.
Human and Robotic Technologies			
APG 4HRT13	Distribute at least 80% of allocated procurement funding to competitively awarded contracts, including continuing and new contract activities.	green	NASA's Exploration Systems Research and Technology team (formerly Human and Robotics Technologies) developed and implemented a competitive funding process for all new research and technology investments. The team also completed an intramural call for proposals with external proposal review that resulted in 50 awards to NASA Centers, with external and cross-Center participation. The team also completed the initial phase of an external call for proposals; 498 Notices of Intent from industry, academia, and other government organizations were approved from over 3,700 Notices received. NASA expects to make awards in November 2004.
International Space Station			
APG 4ISS7	Complete all development projects within 110% of the cost and schedule baseline.	green	The International Space Station program continues to manage within the baseline established by the FY 2004 President's budget. The development phase (element development prior to Shuttle integration) has been within 110% of cost and schedule. Station assembly has been halted while the Space Shuttle fleet is grounded. However, development activity has continued in order to minimize schedule impacts. The FY 2004 Appropriation reduced the Station program by $200 million, but the program maintained the same content. The FY 2005 President's Budget Request maintained the baseline, while adding crew/cargo services content and funding to the program baseline. The Station program plans to re-baseline in FY 2006 after the Shuttle returns to flight.
APG 4ISS8	The ISS Program will complete all of its missions within 10% of its baseline schedules.	green	In keeping with NASA's response to the Columbia Accident Investigation Board, the Agency will be driven by safety rather than schedule. Therefore, NASA will continue to be milestone-driven rather than schedule-driven.
Space Shuttle Program			
APG 4SSP5	Complete all development projects within 110% of the cost and schedule baseline.	green	The Space Shuttle program is pursuing the Advanced Health Management System and Cockpit Avionics Upgrade development projects. Both projects remained within 110% of the cost and schedule baseline.
APG 4SSP6	Space Shuttle Program will execute its program within 10% of its baseline schedules.	green	In keeping with NASA's response to the Columbia Accident Investigation Board, the Agency will be driven by safety rather than schedule. Therefore, as NASA works towards safe return to flight, the Space Shuttle program will continue to be milestone-driven rather than schedule-driven.
Space and Flight Support			
APG 4SFS14	Complete all development projects within 110% of the cost and schedule baseline.	green	Space Flight Support programs are operational in nature and have operated within 110% of their cost and schedule baselines.
APG 4SFS15	Space and Flight Support will execute its programs within 10% of its baseline schedules.	green	In keeping with NASA's response to the Columbia Accident Investigation Board, the Agency will be driven by safety rather than schedule. Therefore, as NASA works towards safe return to flight, this program will continue to be milestone-driven rather than schedule-driven.

Performance Measures for Implementing Strategies		2004 Rating	Comments
Space and Flight Support			
APG 4SFS14	Complete all development projects within 110% of the cost and schedule baseline.	green	Space Flight Support programs are operational in nature and have operated within 110% of their cost and schedule baselines.
APG 4SFS15	Space and Flight Support will execute its programs within 10% of its baseline schedules.	green	In keeping with NASA's response to the Columbia Accident Investigation Board, the Agency will be driven by safety rather than schedule. Therefore, as NASA works towards safe return to flight, this program will continue to be milestone-driven rather than schedule-driven.

Note: See NASA's Performance Improvement Plan at the end of Part 2 for details on FY 2004 APGs and Outcomes rated Red, Yellow, or White.

NASA's Performance Improvement Plan

The following table reports on the performance measures (Outcomes and APGs) that NASA was unable to achieve fully in FY 2004. The table is organized by Strategic Goal. For each Performance Outcome and/or APG that NASA did not achieve fully, the table includes an explanation of the specific performance problem, the reason(s) for less than fully successful performance, and NASA's plan and schedule to achieve or discontinue the Outcome or APG.

Goal	Performance Measure	Description	Rating	Explanation/description of where a performance goal was not met	Why the goal was not met	Plans and schedules for achieving the goal	If the goal is impractical or infeasible, why that is the case and what action is recommended
2	APG 4AT19	Complete detailed design of a low-emission combustor leading to a 2005 test of a full-annular combustor demonstrating a 70% reduction of nitrogen oxides.	Yellow	The design of the low emission combustor is not yet complete.	The schedule slip was a result of the FY 2004 Continuing Resolution and the delay in receiving spending authority (not received until February 2004) to put funds on the contracts for this effort.	Expected completion date is December 30, 2004. This is an interim step toward achieving the FY 2007 goal. There is currently sufficient schedule reserve to accommodate this slip without impacting the final deliverable.	Not applicable
2	APG 4AT9	Experimentally demonstrate a 2-stage highly loaded compressor for increasing pressure rise per stage.	Yellow	The test of the two-stage highly loaded compressor has not yet been accomplished. All the hardware has been fabricated. Assembly and instrumentation currently in progress.	This APG will slip into FY 2005. Most of the compressor components for the facility have been manufactured and have been heavily instrumented since this will be a research facility. Upon installation, a problem occurred with the match balancing of the shafts. Repeatability of the balancing has not been achieved, and further installation of components cannot take place until the shaft is balanced.	Expected completion date is November 30, 2004.	Not applicable
3	APG 4AT14	Conduct and obtain flight test data of autonomous aerial refueling technologies in support of DoD UCAV Program.	White	The project was cancelled before the goal could be achieved.	Funds were redistributed from this project to other higher priority projects.	No current plans to continue this goal.	Not applicable
3	Outcome 3.2.3,	By 2008, develop and test at least two design tools for advanced materials and in-space fabrication, and validate on ISS.	Yellow	PSR is not on track to develop and test at least two design tools for advanced materials and in-space fabrication, and validate on ISS.	Because of the Columbia accident, there have been no Shuttle flights to the ISS. Once the Shuttle resumes flight, there will be limited access to it and the ISS. Since in-space fabrication supports the new Vision for Space Exploration, this goal is still viable. However, validation on the ISS may not be possible.	Once the Shuttle resumes flight, there will be very limited access to it and the ISS.	Not applicable
	APG RPFS4	Continue synthesis of zeolite crystals on ISS.					

Goal	Performance Measure	Description	Rating	Explanation/description of where a performance goal was not met	Why the goal was not met	Plans and schedules for achieving the goal	If the goal is impractical or infeasible, why that is the case and what action is recommended
3	Outcome 3.2.5	By 2008, increase by 30% (from the 2003 level) the utilization of NASA/OBPR-derived technologies by other agencies, private sector, and academia to advance basic and applied research goals of practical impact.	White	This Outcome and its related APG have been superseded by Agency direction. Research content related to this Outcome has been deleted in order to support content better focused on tasks with greater exploration relevance.	Not applicable	Not applicable	Not applicable
	APG 4PSR1	Maintain an active research program in collaboration with other agencies in laser light scattering, bioreactor, and containerless technologies.					
3	Outcome 3.3.1	By 2008, analyze the impact of the results of the first phase of ISS and ground-based research in biotechnology, fundamental science, and engineering to demonstrate the introduction of at least two new design tools and/or process improvements to existing technologies and industrial practices.	White	This Outcome and its related APG have been superseded by Agency direction. Research content related to this Outcome has been deleted in order to support content better focused on tasks with greater exploration relevance.	Not applicable	Not applicable	Not applicable
	APG 4PSR2	Demonstrate the productivity of the research program in combustion, fluids physics, biotechnology, and materials science and accomplish the milestones of ISS research projects.					
4	Outcome 4.2.1	By 2008, complete the first generation of ISS research in colloidal physics and soft condensed matter and demonstrate the ability to control the colloidal engineering of at least two different model structures.	White	This Outcome and its related APG have been superseded by Agency direction. Research content related to this Outcome has been deleted in order to support content better focused on tasks with greater exploration relevance.	Not applicable	Not applicable	Not applicable
	APG 4PSR4	Demonstrate the productivity of the colloidal physics and soft-condensed matter program and accomplish the planned ISS research projects milestones.					
4	Outcome 4.2.2	By 2008, complete the design and fabrication of the first ISS fundamental microgravity physics facility to allow the performance of two capstone investigations in dynamical critical phenomena.	White	This Outcome and its related APG have been superseded by Agency direction. Research content related to this Outcome has been deleted in order to support content better focused on tasks with greater exploration relevance.	Not applicable	Not applicable	Not applicable
	APG 4PSR5	Demonstrate the accomplishments of the ISS fundamental physics facility development milestones and maintain a productive ground and space-based research program in condensed matter physics.					

Goal	Performance Measure	Description	Rating	Explanation/description of where a performance goal was not met	Why the goal was not met	Plans and schedules for achieving the goal	If the goal is impractical or infeasible, why that is the case and what action is recommended
4	Outcome 4.2.3	By 2008, complete the design for the ISS laser-cooling laboratory and demonstrate the feasibility to deploy the most accurate atomic clock in space.		This Outcome and its related APG have been superseded by Agency direction. Research content related to this Outcome has been deleted in order to support content better focused on tasks with greater exploration relevance.	Not applicable	Not applicable	Not applicable
	APG 4PSR6	Demonstrate the accomplishments of the ISS laser cooling and atomic physics facility milestones and maintain an innovative and productive ground and space-based research program in atomic and gravitational physics.	White				
4	Outcome 4.2.4	By 2008, complete the first phase of the ISS biotechnology facility and demonstrate cellular biotechnology research throughput increase by a factor of two.		This Outcome and its related APG have been superseded by Agency direction. Research content related to this Outcome has been deleted in order to support content better focused on tasks with greater exploration relevance.	Not applicable	Not applicable	Not applicable
	APG 4PSR7	Demonstrate the accomplishments of the ISS biotechnology research facility development milestones and maintain a productive and innovative ground and space-based research program in cellular biotechnology and tissue engineering.	White				
5	Outcome 5.1.1	Understand the initial stages of planet and satellite formation.	Yellow	Although NASA made progress in understanding the initial stages of planet and satellite formation, because the parachute on Genesis's sample return capsule did not deploy, the mission received a Yellow rating by the expert external reviewer. (See progress text under Objective 5.1 for details of non-Genesis achievements in this science area.)	Although NASA made progress in understanding the initial stages of planet and satellite formation, because the parachute on Genesis's sample return capsule did not deploy, the mission received a Yellow rating by the expert external reviewer.	Although Genesis scientists expect to achieve most of the science objectives through samples recovered from the capsule, the results will be evaluated during FY 2005 when detailed laboratory analysis is performed. NASA's Science Mission Directorate will request that the expert external review, which will be conducted to evaluate FY 2005 scientific progress, include a reassessment of this FY 2004 rating.	Not applicable
5	APG 4SSE12	Successfully demonstrate progress in understanding the initial stages of planet and satellite formation. Progress towards achieving outcomes will be validated by external review.	Yellow	Although NASA made progress in understanding the initial stages of planet and satellite formation, because the parachute on Genesis's sample return capsule did not deploy, the mission received a Yellow rating by the expert external reviewer. (See progress text under Objective 5.1 for details of non-Genesis achievements in this science area.)	Although NASA made progress in understanding the initial stages of planet and satellite formation, because the parachute on Genesis's sample return capsule did not deploy, the mission received a Yellow rating by the expert external reviewer.	Although Genesis scientists expect to achieve most of the science objectives through samples recovered from the capsule, the results will be evaluated during FY 2005, as detailed laboratory analysis is performed. NASA's Science Mission Directorate will request that the expert external review, which will be conducted to evaluate FY 2005 scientific progress, include a reassessment of this FY 2004 rating.	Not applicable

Goal	Performance Measure	Description	Rating	Explanation/description of where a performance goal was not met	Why the goal was not met	Plans and schedules for achieving the goal	If the goal is impractical or infeasible, why that is the case and what action is recommended
6	APG 4ED9	Develop an inventory identifying the number of first-time proposers and the universe of faculty in higher education institutions involved with NASA research and development opportunities.	Red	The number of first-time proposers in the universe of faculty in higher education has not been catalogued.	NASA has not met this performance goal since it was just initiated in FY 2004, and NASA is tracking that information from all grant proposers.	The question of whether or not a faculty member is proposing for the first time to NASA is now being tracked in FY 2005, and NASA will establish an inventory and baseline.	Not applicable
8	APG 4SSP1	Implement necessary modifications to the Space Shuttle system for return to flight in FY 2004.	Yellow	The Shuttle fleet remained grounded in FY 2004 to allow time to implement all of the return to flight recommendations from the Columbia Accident Investigation Board. NASA continues to perform those activities that will lead to a safe return to flight in FY 2005.	The Final Report of the Columbia Accident Investigation Board identified a number of systemic cultural, organizational, and managerial issues within the Shuttle program and NASA as a whole that contributed to the loss of *Columbia* on February 1, 2003. The Board identified 15 return to flight and 14 long-term recommendations designed to address these issues. The complexity of the technical challenges associated with completing these recommendations has delayed the current return to flight launch window to no earlier than May 2005.	NASA continues to perform those activities that will lead to a safe return to flight in FY 2005. In FY 2004, the Space Shuttle program successfully conditionally closed five of the 15 return to flight recommendations with the Return to Flight Task Group and continued to make progress toward closing the remaining recommendations in early FY 2005.	Not applicable
8	APG 4SSP2	Achieve zero Type-A (damage to property at least $1M or death) or Type-B (damage to property at least $250K or permanent disability or hospitalization of 3 or more persons) mishaps in FY 2004.	Yellow	Although there were no Type A mishaps in FY 2004, NASA failed to achieve this APG due to the occurrence of one Type B mishap.	A Space Shuttle Main Engine #2052 low-pressure fuel duct was damaged while the engine was being moved at the Stennis Space Center. This resulted in $600,000 worth of damage, but no injuries.	The Shuttle program has adopted corrective actions to prevent this type of mishap in the future. Procedures requiring transportation of Space Shuttle Main Engines to and from the test stands and engine shop have been updated to incorporate a Move Director and crew briefing templates to assure all required information is transmitted to the move crews. Approval from the NASA Stennis Space Center Site Director is now required for Space Shuttle Main Engine transports.	Not applicable
8	APG 4SSP3	Achieve 100% on-orbit mission success for all Shuttle missions launched in FY 2004. For this metric, mission success criteria are those provided to the prime contractor (SFOC) for purposes of determining successful accomplishment of the performance incentive fees in the contract.	White	The Space Shuttle fleet remained grounded in FY 2004 to allow time to implement all of the return to flight recommendations from the Columbia Accident Investigation Board.	NASA will not launch the Shuttle until all 15 return to flight recommendations have been adequately addressed, as determined by the Return to Flight Task Group, co-chaired by former astronauts Thomas Stafford and Richard Covey. The complexity of the technical challenges associated with completing these recommendations has delayed the current return to flight launch window to no earlier than May–July 2005.	NASA continues to perform those activities that will lead to a safe return to flight in FY 2005. In FY 2004, the Shuttle program successfully conditionally closed five of the 15 return to flight recommendations with the Return to Flight Task Group and continued to make progress towards closing the remaining recommendations in early FY 2005.	Not applicable

Goal	Performance Measure	Description	Rating	Explanation/description of where a performance goal was not met	Why the goal was not met	Plans and schedules for achieving the goal	If the goal is impractical or infeasible, why that is the case and what action is recommended
8	APG 4ISS2	Achieve zero Type-A (damage to property at least $1M or death) or Type-B (damage to property at least $250K or permanent disability or hospitalization of 3 or more persons) mishaps in FY 2004.	Yellow	There was one Type-B mishap during FY 2004.	In October 2003, a spare Cupola window was crushed at the Dow Corning plant. Damage was estimated at $300,000. There were no injuries. The investigation board concluded its activities in May 2004, after completing of its report on the mishap.	The Cupola mishap investigation report will be reviewed for applicable lessons learned. Safety remains a top priority for the ISS Program, contractors, and their facilities.	Not applicable
10	APG 4HRT8	Establish 3 partnerships with U.S. industry and the investment community using the Enterprise Engine concept.	Yellow	The original performance goal was to establish three partnerships with U.S. industry and the investment community using the Enterprise Engine concept.	The goal has not been met for three reasons. First, this was a new project in FY 2004. NASA was under a continuing resolution, and this project was not funded at the start of the fiscal year. Funding was finally available in the second quarter of FY 2004. Second, although significant interest has been raised by the venture capital and corporate investment communities to start to generate deal flow, of these initial opportunities, none has cleared NASA's investment criteria (i.e., those opportunities serving NASA mission needs and providing multi-use technologies). Third, in deciding to capitalize on the advantages of following the Central Intelligence Agency's In-Q-Tel venture capital opera-ting model, resources have been focused on establishing a non-profit corporation to act as NASA's agent for investment transactions. This is an imperative for the future of this initiative.	The team is working to generate further deal flow, and is currently in the progress of hiring a law firm to assist in the establishment of a non-profit organization to act as NASA's agent for investment transactions. The current forecast is that this organization, complete with the recruitment of a board of trustees, will be completed by the start of calendar year 2005. The first partnership/transaction is forecast to be completed by the end of the second quarter of FY 2005.	No change recommended, this goal will be met or exceeded in FY 2005
10	APG 4AT18	Demonstrate the efficient performance of a flight-prototype regenerative energy storage system in an altitude chamber.	Red	As a result of the loss of the Helios aircraft, the program was reformulated and the altitude chamber test of the flight-prototype regenerative energy storage system was replanned for FY 2009.	The system was designed to be used on the Helios uncrewed aerial vehicle. After the loss of this aircraft, the program was replanned in conjunction with NASA's Earth Science community users. As a result, NASA decided to proceed with development of a more capable uncrewed aerial vehicle rather than build another Helios system. The regenerative energy storage system will be redesigned to support this new vehicle and will undergo altitude chamber testing in FY 2009.	Replanned for improved system to be tested in FY 2009	Not applicable

Goal	Performance Measure	Description	Rating	Explanation/description of where a performance goal was not met	Why the goal was not met	Plans and schedules for achieving the goal	If the goal is impractical or infeasible, why that is the case and what action is recommended
Imple-menting Strategies	APG 4SSE1	Complete all development projects within 110% of the cost and schedule baseline.	Yellow	NASA did not successfully complete MESSENGER mission development within 110% of the cost baseline established at the Mission Confirmation Review.	NASA successfully launched the MESSENGER mission on August 3, 2004. Development and launch of the MESSENGER mission was completed within 110% of the schedule baseline, but exceeded the cost baseline established at the Mission Confirmation Review by 16.5%; this resulted in a Yellow rating on cost (APG 4SSE1) and a Green rating on schedule (APG 4SSE3).	This type of metric cannot be met at a later date. NASA assigns Yellow to those cost and schedule APGs that are missed by a relatively small margin, and Red to those missed by a large margin.	Not applicable
Imple-menting Strategies	APG 4SSE7	Define the Level One science goals for the Jupiter Icy Moons Orbiter (JIMO) Mission	Yellow	Definition of the Level One science goals for the Jupiter Icy Moons Orbiter mission has not been finalized.	The Jupiter Icy Moons Orbiter Science Definition Team recommended goals; however, a change in the planned Jupiter Icy Moons Orbiter launch date and corresponding release of the Announcement of Opportunity delayed the need for final definition.	The Jupiter Icy Moons Orbiter Science Definition Team recommended goals, which are being reviewed by NASA's Science Mission Directorate senior management; final determination is antici-pated in mid-FY 2005.	Not applicable
Imple-menting Strategies	APG 4MEP1	Complete all development projects within 110% of the cost and schedule baseline.	White	Annual Performance Goal not applicable; no Mars Exploration Program missions scheduled for completion or launch in FY 2004.	Not applicable	Not applicable	Not applicable
Imple-menting Strategies	APG 4MEP3	MEP will complete all of its missions within 10% of their baseline schedules.	White	Annual Performance Goal not applicable; no Mars Exploration Program missions sche-duled for completion or launch in FY 2004.	Not applicable	Not applicable	Not applicable
Uniform Measures	APG 4ASO1	Complete all development projects within 110% of the cost and schedule baseline.	White	Annual Performance Goal not applicable; no Mars Exploration Program missions scheduled for completion or launch in FY 2004.	Not applicable	Not applicable	Not applicable
Imple-menting Strategies	APG 4ASO3	ASO will complete all of its missions within 10% of their baseline schedules.	White	Annual Performance Goal not applicable; no Mars Exploration Program missions scheduled for completion or launch in FY 2004.	Not applicable	Not applicable	Not applicable
Imple-menting Strategies	APG 4ASO5	Successfully complete Stratospheric Observa-tory for Infrared Astronomy (SOFIA) Observatory Flight Test	Yellow	The Stratospheric Observatory for Infrared Astronomy did not complete its flight test.	Several aerospace vendor problems were encoun-tered, including vendor bankruptcy and parts not manufactured to speci-fications, requiring re-manufacturing. Also, it proved much more chal-lenging than anticipated to install the German telescope into the 747 airplane to conduct key integration tests following the installation and to conduct the major ground test of the airplane modification (i.e., fuselage proof pressure test).	NASA overcame these problems, but the flight test is delayed until FY 2005.	Not applicable

Goal	Performance Measure	Description	Rating	Explanation/description of where a performance goal was not met	Why the goal was not met	Plans and schedules for achieving the goal	If the goal is impractical or infeasible, why that is the case and what action is recommended
Implementing Strategies	APG 4SEU1	Complete all development projects within 110% of the cost and schedule baseline.	Red	NASA did not successfully complete Gravity Probe B and Swift mission development within 110% of the cost baseline established at the Mission Confirmation Reviews.	NASA successfully launched the Gravity Probe B mission in April 2004. However, development and launch of the mission far exceeded the cost (by 37%) and schedule baselines established at the Mission Confirmation Review due to unprecedented technical challenges. Completion and launch of the Swift spacecraft was also scheduled for FY 2004; however, due to technical problems and, more recently, hurricane-related delays, the launch is now scheduled for November 2004. Swift also will exceed the schedule threshold, and will exceed the cost baseline by approximately 40%.	This metric cannot be met at a later date. NASA assigns Yellow to those cost and schedule APGs that are missed by a relatively small margin, and Red to those missed by a large margin. When the Gravity Probe B program was cancelled three times due to poor performance (and Congressional appropriators restored its funding each time), NASA reviewed the program to restrain cost and schedule growth. NASA held project managers to strict standards for mission progress, with cancellation as the alternative if standards were not met. In early 2003, an independent review team evaluated mission development progress to date. The team put forth requirements for continuation. The project implemented them and Gravity Probe B launched in April 2004.	Not applicable
Implementing Strategies	APG 4SEU3	SEU will complete all of its missions within 10% of their baseline schedules.	Red	NASA did not successfully complete Gravity Probe B and Swift mission development within 110% of the schedule baseline established at the Mission Confirmation Reviews.	NASA successfully launched the Gravity Probe B mission in April 2004. However, development and launch of the mission far exceeded the schedule baseline established at the Mission Confirmation Review due to unprecedented technical challenges. Completion and launch of the Swift spacecraft was also scheduled for FY 2004; however, due to technical problems and, more recently, hurricane-related delays, the launch is now scheduled for November 2004. Swift also will exceed the schedule threshold.	This metric cannot be met at a later date. NASA assigns Yellow to those cost and schedule APGs that are missed by a relatively small margin, and Red to those missed by a large margin. When the Gravity Probe B program was cancelled three times due to poor performance (and Congressional appropriators restored its funding each time), NASA reviewed the program to restrain cost and schedule growth. NASA held project managers to strict standards for mission progress, with cancellation as the alternative if standards were not met. In early 2003, an independent review team evaluated mission development progress to date. The team put forth requirements for continuation. The project implemented them and Gravity Probe B launched in April 2004.	Not applicable

Goal	Performance Measure	Description	Rating	Explanation/description of where a performance goal was not met	Why the goal was not met	Plans and schedules for achieving the goal	If the goal is impractical or infeasible, why that is the case and what action is recommended
Imple-menting Strategies	APG 4SEU5	Successfully launch Swift.	Yellow	Swift was not success-fully launched.	The Swift launch date slipped from December 2003 to September 2004 due to technical difficulties with instrument develop-ment and the replacement of a damaged instrument power electronics board. The slip from September 2004 to November 2004 is due to launch pad sche-duling and hurricane-related delays.	The launch is scheduled for November 2004.	Not applicable
Imple-menting Strategies	APG 4SEC1	Complete all development projects within 110% of the cost and schedule baseline.	White	This APG was not applicable; no Sun–Earth Connection missions were sche-duled for completion and launch in FY 2004.	Not applicable	Not applicable	Not applicable
Imple-menting Strategies	APG 4SEC3	SEC will complete all of its missions within 10% of their baseline schedules.	White	This APG was not applicable; no Sun–Earth Connection missions were sche-duled for completion/ launch in FY 2004.	Not applicable	Not applicable	Not applicable
Imple-menting Strategies	APG 4SEC4	Begin Solar Terrestrial Relations Observatory (STEREO) Integration and Testing (I&T)	Yellow	The STEREO mission did not begin inte-gration and testing.	Integration and testing slipped three months due to industry-wide thruster valve problems.	Integration and testing is currently scheduled to start at the end of January 2005. This delay has resulted in a three-month slip to the launch date (now February 2006), with a corresponding delay in the start of mission science. STEREO will measure the causes and mechanisms of Coronal Mass Ejection initiation and character-ization of their propagation through the heliosphere.	Not applicable
Imple-menting Strategies	APG 4SEC6	Release Announcement of Opportunity (AO) for Geospace Missions	Yellow	Announcement of Opportunity for Geospace Missions was not released.	The Announcement of Opportunity is on hold while the cost of the program is reassessed in recognition of new budget priorities.	Upon receiving an approved program budget and a new set of Explo-ration-prioritized goals, a timeline for the release of the Geospace Announce-ment of Opportunity will be determined.	Not applicable
Imple-menting Strategies	APG 4ESS3	Development: Each project will complete its mission within 10% of its baseline schedules.	Red	The Earth Science program examined schedule changes for three projects in mid-FY 2004, and the average increase in develop-ment schedule from the initial baseline estimate to the FY 2006 budget submit was 13%.	Calipso and Cloudsat were the two projects over the 10% performance metric. Several technical issues led to poor schedule performance, thus increasing mission cost.	This poor performance initiated a subsequent re-baseline activity. At this time, there are no changes anticipated. Projects are now under new baseline controls.	The goal is prac-tical and feasible. Action was taken to resolve the problem (e.g., the activity was re-baselined, and NASA expects that the new baseline controls will enable this goal to be achieved in FY 2005).
Imple-menting Strategies	APG 4AT1	Complete all development projects within 110% of the cost and schedule baseline.	White	Annual Performance Goal was not applicable since there were no development projects within the Aeronautics Theme.	Not applicable	Not applicable	Not applicable